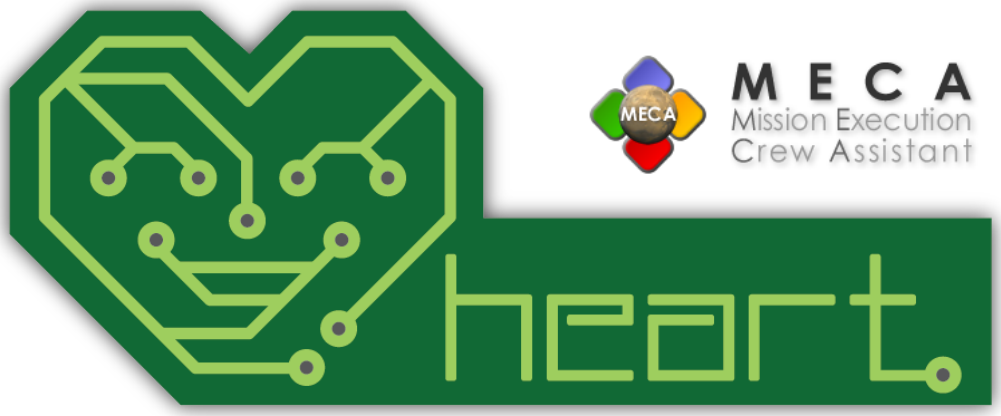





# MECA-HEART WP3 D2b **Technical Note** "Mission Simulation Specification"

| | |
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| **1.4** | 15- May | Nanja Smets | Added requirements to design scenario, added appendix B, nominal scenario to Appendix C, merged Method section and experiment leader instruction section |
| | | | |
| **1.5** | 20-May | Frank Plaßmeier | Added mission simulation scripts for problem scenario. |
| **1.6** | 03-June-2015 | Frank Plaßmeier | Version for SRR: Mission planning primarily assigned to Albert (now mission commander, Hannah acts as support engineer), removed obsolete notes on limitations of the software, editorial corrections. |
| | | | |
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# ACRONYMS

| Acronym | Definition |
|---|---|
| **A** | Albert |
| **CTL** | Cognitive Task Load |
| **EGP** | Eurobot Ground Prototype |
| **ePartner** | Electronic Partner |
| **H** | Hannah |
| **HEART** | Human E-partner Agent Robot Teaming |
| **MECA** | Mission Execution Crew Assistant |
| **RB** | Requirements Baseline |
| **RM1** | First Review Meeting |
| **R1** | Rover 1 |
| **SA** | Situation Awareness |
| **sCE** | Situated Cognitive Engineering (method) |
| **sCET** | Situated Cognitive Engineering Tool |
| **UCD** | User-Centered Design |
| **UI** | User Interface |
| **UX** | User Experience |

# 1 DOCUMENT OVERVIEW

This document provides the required information for preparing and executing mission scenario simulations for the MECA HEART project. In chapter 2, the revised mission scenario is first introduced, then described and finally decomposed into simulation steps. Chapter 3 describes the methodical approach to experiment and evaluation. Chapter 4 consists of detailed mission simulation scripts on a per-actor basis. Chapter 5 then provides detailed instructions for experiment subjects and the experiment leader. Chapter 6 lists for reference the complete set of rules used by the inference engine during the scenario. Chapters 7, 8 and 9 contain appendices that provide further reference information.

As this document contains several tables with a large number of columns, landscape page layout has been selected in some sections for the convenience of readers.

# 2 REVISED MISSION SCENARIO

The outlined mission scenario is intended to set the frame for the simulation of combined crew and robotic activities for achieving mission objectives of a future Mars exploration mission in order to evaluate the MECA-HEART prototype of an advanced, ePartner-based mission support system.

The Hypotheses of the MECA-Heart prototype have been described in Section 5 of document "MECA-HEART WP1 - D1a HEART Requirements". The scenario is designed in such a way that each hypothesis can be tested. The most prominent measures of performance against which MECA-Heart will be assessed are:

- **Effectiveness**. In the scenario, this means the ability to complete the mission objective (setting up the cache), despite of unfortunate events (i.e. resilience).
- **Efficiency**. In the scenario, this means that the workload of the human actors will be reduced by the MECA-Heart prototype. This aspect applies to every phase of the scenario (preparation, mission execution, and returning to the habitat).
- **Situation awareness**. In the scenario, this means that the involved actors (both the astronaut on EVA, and the astronaut in the habitat), are aware of and understand the environment around them and to predict potential consequences (e.g. potential dangerous situations).
- **Safety.** Safety plays an important role in the scenario. For example, walking back to the habitat without the robot is regarded as an unsafe course of action.
- **Satisfaction.** In the scenario, both the astronaut on EVA and the astronaut in the habitat interact extensively with the prototype. This allows the opportunity to assess user satisfaction.

The data that is collected to assess these measures are described in Section 5.3.

Wherever possible, standard practices for space operations and the NASA Human Exploration of Mars Design Reference Architecture 5.0 have been taken into account to ensure that the scenario is reasonably realistic. This was for example the reason for changing the EVA task from setting up a greenhouse to setting up a cache for exploratory traverses. However, in some cases operational realism has been sacrificed in order to limit the effort for the simulation runs. In particular, single astronaut EVAs have been assumed to reduce the required number of experiment subjects.

## 2.1 SCENARIO DESCRIPTION

The scenario description is intended to provide overview information at a relatively high level of abstraction for identifying the tasks that need to be performed for achieving the outlined objectives.

### 2.1.1 CONTEXT

Six astronauts and four Rovers of varying types and sizes have landed on Mars. Basic infrastructure, like a habitat, electricity and wireless network communication is available. The rovers are ready for deployment and are currently in the habitat. Part of the crew, consisting of two persons and one rover, is dedicated to the task of setting up a cache for exploratory traverses at a remote location. The shelter for the cache is currently stored in the habitat and can be carried by the Rover to the planned location. At the location, the shelter can be set up as a self-construction kit by unfolding it and by fixing it on the ground by drilling holes in the surface and by placing the poles of the shelter in these holes. The robot is equipped with a drill to do the drilling. The shelter is planned to be placed on a relatively flat location around 12 km from the habitat. The exact location of the shelter has not been decided yet as it depends on the presence of medium-sized stones that may make the area unsuitable as an exploratory cache location, but are too small to be detected on imagery made available to the crew. Communication with ground control on Earth is possible

from the habitat, but is delayed 8 minutes (one way) for the distance between Mars and Earth at the time shortly after landing, and sometimes unavailable due to interference with the Sun.

### 2.1.2 INITIAL PLAN

The plan is carried out by a support engineer who remains in the habitat, called Hannah, and an astronaut on EVA, acting as the mission commander, called Albert. Albert uses the rover for transportation over the Mars' surface, and to help him with heavy work such as moving rocks and drilling holes. Hannah monitors the robot and Albert from the habitat, and has access to the following sensor data:

- On the rover:
  - Eight camera feeds provided by the Rover
  - Temperature
  - Battery level
  - Wheel orientation of each wheel
  - Robotic arm orientation
  - Signal strength of the communication network.
- On Albert:
  - Heart rate
  - Compressed air pressure levels of spacesuit,
  - Temperature inside the space suit,
  - Cognitive workload

The sensor data is sent from the EVA team to the habitat periodically in predefined packages. The transmission cycle time for these packages has to be specified manually. Furthermore, for most sensors (e.g. rover's battery, spacesuit air pressure, etc.) threshold values have been built in that automatically communicate alarms to the habitat.

The initial plan of setting up the cache distinguishes in four phases:

1. **Preliminary preparation**. Albert and robot are still in the habitat and pick a site on the map, and make a plan of the mission.
2. **Clearing the surface.** Albert and robot are on EVA and prepare the area for deploying the shelter.
3. **Construction.** Albert and robot set up the shelter on the surface.
4. **Return to the habitat.** Albert and robot return back to the habitat.

We will describe a problem scenario (a sequence of events without ePartner support), and a design scenario (a sequence of events with ePartner support). The scenario is summarized in the two figures below. Green lines show the nominal situation, blue lines show an off-nominal situation and red lines show a failed mission. Figure 1 shows the problem scenario in which only one branch results in a successful mission, the design scenario in figure 2 shows the actors having ePartner support (indicated by its logo) which should result in a successful mission in each branch.

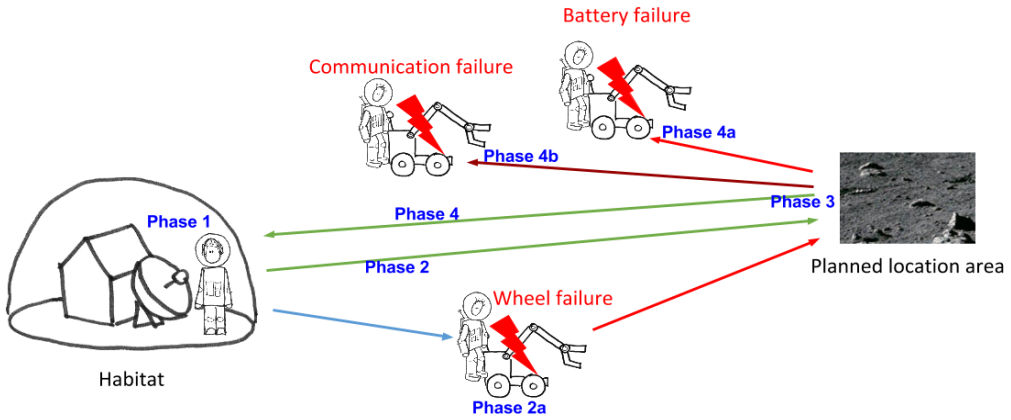


Figure 1: Problem Scenario with Nominal and Off-Nominal Branches

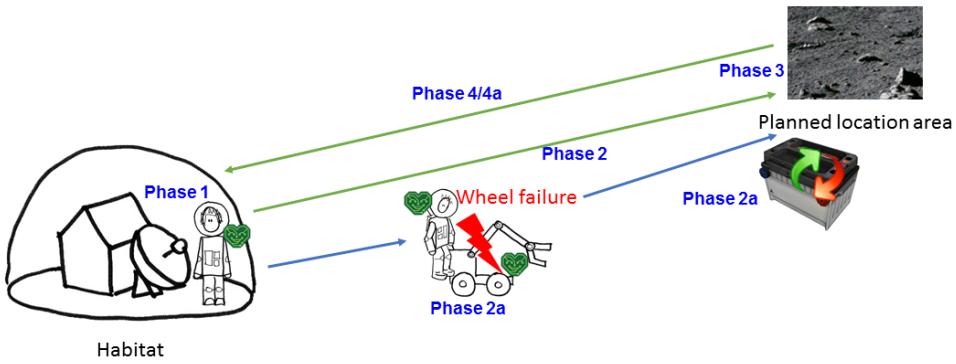


Figure 2: Design Scenario with Nominal and Off-Nominal Branches

### 2.1.3 PROBLEM SCENARIO OUTLINE (WITHOUT EPARTNER SUPPORT)

**Phase 1: Preliminary preparation**

*Hannah and Albert work together in the habitat to plan the mission*.

1. Hannah and Albert mark a location on a map (on a tablet device) 12km from the habitat which they believe is a good location.
2. Albert marks a route to the planned location, and derives travel time.
3. Albert schedules the different phases in the agenda on the tablet device.
4. Albert makes a list of the required inventory (tools, energy, etc.). This is done by manually looking up the required inventory from an existing table. That table contains a description of needed equipment per action in each possibly selectable phase/step.

**Phase 2: Clearing the surface - nominal situation**

*Albert and Rover travel to the planned location and clear the surface. Hannah remains in the habitat and monitors the mission.*

5. Albert controls the Rover and drives it to the planned location.
6. Hannah keeps track of camera feeds provided by the Rover, keeps a sharp eye on any incoming alarms, and occasionally requests sensor data like heart rate, internal (compressed air) pressure levels.
7. Albert confirms to Hannah that they reached the spot using their headset.
8. Albert instructs Rover to move unwanted rocks out of the selected area.
9. Hannah is still monitoring but does not notice any abnormalities.
10. Rover successfully finished moving the rocks.

**Phase 2a: Clearing the surface - off-nominal situation**

5. Albert controls the Rover and drives it to the planned location
6. Hannah keeps track of camera feeds provided by the Rover, keeps a sharp eye on any incoming alarms, and occasionally requests sensor data like heart rate, internal (compressed air) pressure levels.
7. Halfway to the desired location, the Rover experiences an error: one of the wheels fails to turn back to the original position.
8. The Rover stops driving and starts its recovery procedure (FDIR): try turning the incorrectly oriented wheel back to its desired orientation. This partly succeeds: the wheel turns back but is still off by a slight angle of a few degrees.
9. Since the wheel is only off by a few degrees, this hardly affects the driving capabilities of the rover. After a warning that FDIR failed, Albert agrees with Hannah to continue the journey.
10. Albert confirms to Hannah that they reached the spot using their headset.
11. Albert instructs Rover to move unwanted rocks out of the selected area.
12. During this entire mission, the Rover's battery level is shown on Hannah's display together with all other information, so without a real emphasis.
13. Rover successfully finished moving the rocks.

**Phase 3: Construction**.

14. Albert instructs the robot arm to employ the drilling tool and places the arm in the right location.
15. Albert enters drill depth and instructs the robot to create the holes.
16. Albert takes the cache construction kit out of the Rover and unfolds it.
17. Albert finds the correct pole for each hole and places them in the corresponding holes.

**Phase 4: Return to habitat - nominal situation based on Phase 2**

18. Hannah is occasionally requests sensory data information from the robot (e.g. on battery level). Hannah sees that the Rover's battery level should be just enough to get back to the habitat. Since the exploratory cache is erected successfully, the journey back to the habitat is commenced.
19. During the trip back, all data is continuously monitored and Hannah notices everything is going according to plan.
20. Albert arrives back at the habitat and the mission is completed.

**Phase 4a: Return to habitat - off-nominal (following Phase 2a)**

18. Hannah is (still) receiving all sensory data information from the robot (e.g. on battery level). The battery level is lower than it should be at this stage of the mission, but still within technical limits. Therefore no special notification is provided. Since the exploratory cache is erected successfully, the journey back to the habitat is commenced.
19. There is a huge setback: the wheel orientation problem of the Rover created an extra drag / load on the motor, draining the battery more quickly than expected. The remaining battery level turns out to be not enough to cover the trip back to the habitat. The battery level falls below the lower warning limit is reached and a warning message is generated. Finally, the Rover stops moving halfway with a depleted battery.
20. Albert still needs to get back to the habitat. This requires a walk without aid from the Rover, which adds risk to the mission. Furthermore recovery of the Rover requires additional resources and time and therefore adversely affects the mission schedule, potentially reducing the achievable results of exploratory activities.

**Phase 4b: Return to habitat - off-nominal (following Phase 2)**

18. Hannah is (still) receiving all sensory data information from the robot (e.g. on battery level). Suddenly, the transmission signal is interrupted and she loses all communication with the Rover
19. Albert also receives the warning about the communication signal being lost. He has to decide himself what to do now: wait until communication is restored (if this will ever happen), wait for Hannah to pick him in a rescue mission, continue the mission, or abort and directly try to find the habitat without having a possibility to keep Hannah informed about his status.
20. Albert decides it is too risky to stay where he is with a limited amount of oxygen and battery, so he decides to try and find the habitat manually. Operating the Rover without communications channel is possible, but his navigational abilities are limited since only a backup navigation system is available and everything now is operated manually and he has to keep track of the sensory data of the Rover himself as well. This adds risk to the mission

### 2.1.4 DESIGN SCENARIO OUTLINE (WITH EPARTNER SUPPORT)

**Phase 1: Preliminary preparation**

1. Hannah and Albert plan the mission together in the habitat.
2. Albert's ePartner suggests a location that is suitable for building an exploratory cache.
3. ePartner plans route to the location, and derives travel time.
4. ePartner suggests a schedule with the different phases.
5. ePartner proposes required inventory (oxygen supply, several batteries to provide power for future exploratory traverses & other items), by deriving this from background knowledge (CWA).

**Phase 2: Clearing the surface - nominal situation**

6. Albert's ePartner controls the Rover and drives it to the planned location.
7. Hannah monitors the processes on her ePartner.
8. Albert's ePartner confirms to Hannah's ePartner that they reached the spot.
9. Albert delegates to the ePartner to instruct the Rover for moving unwanted rocks from the selected area.
10. Hannah gets process updates on her ePartner during the entire mission.
11. The Rover successfully finished moving the rocks.

**Phase 2a: Clearing the surface - off-nominal situation**

6. Albert's ePartner controls the Rover and drives it to the planned location.
7. Hannah monitors the processes on her ePartner.
8. Halfway to the desired location, the Rover experiences an error: one of the wheels is turned in a different angle compared to the other three (off by a slight angle of a few degrees.
9. The Rover stops driving and starts its recovery procedure (FDIR): try turning the incorrectly oriented wheel back to its desired location. This process and the implication on battery usage are presented to Albert.
10. Since the malfunctioning wheel is expected to cause a higher load on the battery, several alternatives are valued by the ePartner and presented in a "team huddle" to both Albert and Hannah. This can be alternatives like continuing to the intended location (risk on early battery depletion), aborting mission and directly returning to the habitat (failed mission), allocating a 'second-best' spot closer to the habitat to deploy the exploratory cache (reduced utility of cache), or exchanging the drained battery with one initially intended to be stored in the cache (slightly reduced utility of cache). (see figure 2)
11. Albert and Hannah agree on the changed mission with battery exchange. Albert's ePartner confirms to Hannah's ePartner that they reached the intended spot.
12. Albert exchanges the batteries and informs Hannah accordingly.

13. Albert delegates to the ePartner to instruct the Rover for moving unwanted rocks from the selected area.
14. Hannah gets process updates on her ePartner during the entire mission.
15. The Rover successfully finished moving the rocks.

**Phase 3: Construction**

16. Albert selects the construction phase on his ePartner.
17. Albert's ePartner configures and controls the robot to drill the holes.
18. Albert takes the cache construction kit out of the Rover and unfolds it.
19. Albert gets instruction from the ePartner indicating which pole he has to put in which corresponding hole.

**Phase 4: Return to habitat - nominal situation**

20. Hannah's ePartner is receiving information from the robot and sees that all processes are OK. Since the cache is erected successfully, the ePartner indicates the journey back to the habitat is commenced.
21. The ePartners of both Albert and Hannah indicate the expected arrival time and make sure the robot has enough battery level to finish the journey. In case of previous phase 2a (changed location), the decision to exchange the batteries proved to be right: the battery level is getting lower more quickly than originally anticipated for, battery capacity of old battery would not have been sufficient.
22. Albert returns to habitat safely and the mission is completed.

**Phase 4a: Return to habitat - off-nominal situation**

20. Hannah's ePartner is receiving information from the robot and sees that all processes are OK. Suddenly, the transmission signal is interrupted and she loses all communication with the Rover.
21. Both Albert and Hannah get a warning from their ePartners that the communication signal is lost. Alberts ePartner records data to be sent to the habitat when communication is re-established.
22. Hannah's ePartner supports Hannah with predicted values of Alberts location, and helps preparing a rescue plan in case the communication is not restored within a certain period of time.
23. Albert's ePartner supports Albert by informing him about the possibility to keep waiting at the current location, or continue the mission without communication to the habitat. Since the cache has been erected successfully, the ePartner indicates an autonomous journey back to the habitat with backup navigation equipment is the safest option.
24. Rover operation and navigation by means of backup navigation system is done by the ePartner, giving Albert time to try reestablishing the connection to the habitat.

25. As the Rover closes in on the habitat, the connection is reestablished and Albert returns to the habitat safely. The mission is completed.

## 2.2 STEPWISE DECOMPOSITION

The stepwise decomposition of the mission scenario provides the next level of detail by outlining actions that are taken by the involved actors for performing the tasks identified in the scenario description.

### 2.2.1 PROBLEM SCENARIO

The stepwise decomposition of the problem scenario is shown by a set of tables according to the following format:

1. The first column contains a number identifying each step.
2. The second column identifies the actor(s) that performs the action described in the step.
3. The third column identifies the target, i.e. the actor(s) affected by the action (receiving a message or being changed in some way as result of the action).
4. The fourth column describes the action.
5. The fifth column indicates the effect that the action will have on the middle tab (the 'overview') on the target ePartner(s).
   (note that only a 'minimalistic' version of the ePartner is meant here)
6. The sixth column indicates the effect that the action will have on the right tab (the 'detailed view') on the target ePartner(s).
7. The seventh column indicates the effect that the action will have on the underlying knowledge base
8. The eighth column indicates the corresponding step in the relevant scenario outline from chapter 2.1.

| Step | A | T | Action | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Outline Step |
|---|---|---|---|---|---|---|---|
| *Phase 1: Preliminary preparation (without ePartner)* | | | | | | | |
| 00005 | H | A | Hannah and Albert sit down to plan mission. | | | | 1 |
| 00010 | A | Tablet | Albert logs in on his device with a *username* and *password* | | | | 1 |
| 00020 | A | Tablet | Albert looks up the procedures in documentation (PDF) and requirements for setting up a shelter for the cache. | | | | 1 |
| 00060 | A, H | Tablet | Albert opens digital map on tablet to look for suitable location with given constraints of building up a shelter. Albert marks a good location, Hannah agrees. | | | | 1 |
| 00030 | A | Tablet | Albert marks a route to planned location (on digital map), and calculates travel time by means of utility tool on tablet. | | | | 2 |
| 00070 | A | Tablet | Albert schedules different phases of mission and enters them into utility tool on tablet. | | | | 3 |
| 00080 | A | Tablet | Albert looks through documentation (PDF) for the required inventory and makes a list. | Albert clicks tab resources and sees resources. | Detailed information of resources is shown | | 4 |

**Table 1: Stepwise Decomposition of Problem Scenario (without ePartner) Phase 1**

| Step | A | T | Action | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Outline Step |
|---|---|---|---|---|---|---|---|
| *Phase 2a: Clearing the surface – off-nominal condition (without ePartner)* | | | | | | | |
| 02000 | A | R1 | Load supplies onto rover and mount it | | | | 5 |
| 02005 | H | Tablet | Hannah logs in on her device with a *username* and *password* to obtain access to the mission data | | | | 5 |
| 02010 | A | R1 | Albert gives Rover1 command to drive to planned location. He goes to control of rover screen and pushes button. | | | | 5 |
| 02020 | H | Tablet2 | Hannah keeps track of camera feeds provided by Rover, looks out for alarms and requests sensor data. | | | | 6 |
| 02030 | R1 | | Problem with Rover1 and it stops driving (one of the wheels is turned in a different angle compared to the other three, off by a slight angle of a few degrees) | | | | 7 |
| 02040 | R1 | Tablet 1 and 2 | Rover1 gives alarm that there is a problem and FDIR has started. | A warning 'There is a problem with the Rover, | | The wheel status of Wheel 1 has changed. | 8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | recovery procedure has been started' | | | |
| 02045 | R1 | | Rover1 is able to turn wheel back partly. | | | | 8 |
| 02050 | R1 | Tablet 1 and 2 | Rover1 gives alarm that FDIR failed to turn back wheel completely | A warning 'FDIR has failed, wheel 1 has a deviation of 1%' | | The wheel status of Wheel 1 has changed to deviation of 1%. | 9 |
| 02070 | A | H | Albert and Hannah discuss problem, look in documentation and decide to continue mission. Albert commands rover to continue trip to cache site. | | | | 9 |
| 02080 | A, | Tablet | Albert sees that location has been reached. | | | | 10 |
| 02090 | A. | H | By voice Albert confirms to Hannah that he has reached the planned location. | | | | 10 |
| 02100 | A | Tablet | Albert looks in agenda what the next step is. | | | | 11 |
| 02120 | A | R1 | Albert instructs Rover to move unwanted rocks out of the selected area. Albert goes to control of rover screen and gives the command. | | | | 11 |
| 02130 | H | Tablet2 | Hannah keeps track of camera feeds provided by Rover, looks out for alarms and requests sensor data. | | | | 12 |
| 02140 | R1 | A,H | Rocks have been removed from area, show current status in resource screen (process screen?). | | | | 13 |

**Table 2: Stepwise Decomposition of Problem Scenario (without ePartner) Phase 2a**

| Step | A | T | Action | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Outline Step |
|---|---|---|---|---|---|---|---|
| *Phase 3: Construction (without ePartner)* | | | | | | | |
| 03010 | A | R1 | Albert instructs arm to employ drilling tool and places the arm in right location. He goes to control of rover screen and pushes button. | | | | 14 |
| 03030 | A | R1<br>LD | Albert enters drill depth and instructs the robot to create the holes. He goes to control of rover screen and inputs information. | | | The status of Rover1 and LargeDrill have changed to '*operational*'. | 15 |
| 03050 | A | Rover1 | Albert looks at progress of Rover1 in real world and resource screen. When Rover1 has drilled al the holes he takes out cache construction kit out of the Rover and unfolds it. | | | The status of Rover1 and LargeDrill have changed to '*finished*'. | 16 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 00355 | H | Tablet2 | Hannah keeps track of camera feeds provided by Rover, looks out for alarms and requests sensor data | | | | 16 |
| 03060 | A | Tablet | Albert looks in documentation (PDF) what poles go in which hole. | | | | 17 |
| 03085 | A | | Fill cache with supplies | | | | 17 |

**Table 3: Stepwise Decomposition of Problem Scenario (without ePartner) Phase 3**

| Step | A | T | Action | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Outline Step |
|---|---|---|---|---|---|---|---|
| *Phase 4a: Return to habitat – off-nominal condition (without ePartner)* | | | | | | | |
| 05010 | A | H | Albert communicates that task is completed and he is going back to habitat. | | | | 18 |
| | | | | | | | |
| 05040 | A | Rover1 | Albert mounts rover and commands it to drive back to the habitat. | | | | 18 |
| 05045 | H | Tablet2 | Hannah keeps track of camera feeds provided by Rover, looks out for alarms and requests sensor data. | | | | 18 |
| 05050 | Tablet | A | There is a huge setback: the wheel orientation problem of the Rover created an extra drag / load on the motor, draining the battery more quickly than expected. The remaining battery level turns out to be not enough to cover the trip back to the habitat. The battery level falls below the lower warning limit is reached and a warning message is generated. Finally, the Rover stops moving halfway with a depleted battery. | Alarm is given that battery level is below lower warning limit | | The *BatteryStatus* of *Battery1* decreases gradually. | 19 |
| 05100 | A | H | Albert still needs to get back to the habitat. This requires a walk without aid from the Rover, which adds risk to the mission. Furthermore recovery of the Rover requires additional resources and time and therefore adversely affects the mission schedule, potentially reducing the achievable results of exploratory activities. Albert notifies Hannah on voice loop and commences walk back to the habitat. | | | | 20 |
| 05170 | A,R1 | A,H | Assumption: Albert arrives back at habitat and mission is completed, Albert communicates arrival to Hannah. | | | | 20 |

**Table 4: Stepwise Decomposition of Problem Scenario (without ePartner) Phase 4a**

| Step | A | T | Action | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Outline Step |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Phase 4b: Return to habitat – off-nominal condition (without ePartner)* | | | | | | | |
| 06010 | A | H | Albert communicates that task is completed and he is going back to habitat. | | | | 18 |
| 06030 | H, A | Tablet | Hannah requests sensory data information from robot. Hannah sees that the Rover1 battery level should be enough to get back to the habitat. Hannah and Albert decide to commence journey back to habitat. | | | The *BatteryStatus* of *Battery1* decreases gradually. | 18 |
| | A | Rover1 | Albert mounts rover and commands it to drive back to the habitat. | | | | 18 |
| | H | Tablet2 | Hannah keeps track of camera feeds provided by Rover, looks out for alarms and requests sensor data. | | | | 18 |
| 06040 | Tablet | H | Hannah loses communication with Rover1. | Alarm is given that transmission signal is interrupted. | | The communication status of *Communication System* becomes *dysfunctional*. The status of the function '*communication*' becomes *compromised*. | 18 |
| 06050 | Tablet | A | Albert also receives the warning about the communication signal being lost. He has to decide himself what to do now: wait until communication is restored (if this will ever happen), wait for Hannah to pick him in a rescue mission, continue the mission, or abort and directly try to find the habitat without having a possibility to keep Hannah informed about his status. | Alarm is given that transmission signal is interrupted | | | 19 |
| 06100 | A | | Albert decides it is too risky to stay where he is with a limited amount of oxygen and battery, so he decides to try and find the habitat manually. Operating the Rover without communications channel is possible, but his navigational abilities are limited since only a backup navigation system is available and everything now is operated manually and he has to keep track of the sensory data of the Rover himself as well. This adds risk to the mission | | | | 20 |
| 06170 | A,R1 | A,H | Assumption: Albert arrives back at habitat and mission is completed, Albert communicates arrival to Hannah. | | | | 20 |

**Table 5: Stepwise Decomposition of Problem Scenario (without ePartner) Phase 4b**

### 2.2.2 DESIGN SCENARIO

The stepwise decomposition of the design scenario is shown by a set of tables according to the following format:

1. The first column contains a number identifying each step.
2. The second column identifies the actor(s) that performs the action described in the step.
3. The third column identifies the target, i.e. the actor(s) affected by the action (receiving a message or being changed in some way as result of the action).
4. The fourth column describes the action.
5. The fifth column includes additional details about the way how the action will be performed and links to the requirements and claims (in brackets).
6. The sixth column indicates the effect that the action will have on the left tab (the 'ECA view') on the target ePartner(s).
7. The seventh column indicates the effect that the action will have on the middle tab (the 'overview') on the target ePartner(s).
8. The eighth column indicates the effect that the action will have on the right tab (the 'detailed view') on the target ePartner(s).
9. The ninth column indicates the effect that the action will have on the underlying knowledge base
10. The tenth column indicates the rules required to generate the effect on the knowledge base described in the ninth column (in pseudo code).
11. The eleventh column indicates the corresponding step in the relevant scenario outline from chapter 2.1.

| Step | A | T | Action | Reqs | Effect left tab (ECA) | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Rules required | Outline Step |
|---|---|---|---|---|---|---|---|---|---|---|
| *Phase 1: Preliminary preparation (with ePartner)* | | | | | | | | | | |
| 00005 | H | A | Hannah and Albert sit down to plan mission, | | | | | | | 1 |
| 00010 | A | eP | Albert logs in on his device with a *username* and *password* | | | | | | | 1 |
| 00020 | A | eP | Albert opens the processes tab.<br><br>Albert instructs the ePartner to add a new *process* by clicking on the 'Add new process' button. (Hannah looks at the same screen and helps Albert plan the mission) | | A question 'What do you want to do?' appears, with at least one button, e.g. 'Add new process'. | Initially only an empty list is shown. | | | | 1 |
| 00025 | A | eP | Albert's ePartner asks to select a process to be deployed. | | A question 'Which process do you want to deploy?' appears. | A list appears of all processes that exist in the database, from which the user should select one. | | | | 1 |
| 00030 | A | eP | Albert selects a (previously defined) *process* from the process archive. She selects the process instance *'cache construction process'*. | R014 | | The process *'cache construction process'* is highlighted. | Details of the process *'cache construction process'* are shown (i.e., a sequence of tasks). The status of the process is indicated as 'idle'. Also, a 'deploy' button is shown. | | | 1 |
| 00040 | A | eP | The process is added (by Albert, by clicking the 'deploy' button), and<br>the *status* of the first *task* of the *process* becomes '*busy*'. This task is called *plan mission*. | R024 (EFS)<br>R027 (EFS) | A message 'The process has been deployed!' appears. | | The 'deploy' button is not shown anymore. The status of the process is indicated as 'deployed'.<br>The first task (*plan mission*) is highlighted to indicate that it is *busy*. | The status of the process '*cache construction process'* becomes 'deployed'.<br>The status of the task '*plan mission*' becomes *busy*. | OR1<br><br><br><br>OR14 | 1 |
| 00050 | eP | eP | The first task is allocated to the role *MissionCommander*, which is enacted by Albert. | R059, R008, R003 (AUT, EFY, EFS, SAF, EMO, SAT, SAW) | | | | Task *plan mission* is allocated to role *mission commander*, which is enacted by Albert. | DR1 | 1 |
| | eP | eP | Therefore, the tasks pops up in the 'my tasks' list of Albert. | R025 (EFS) | | The task *'plan mission*' is highlighted in the 'my tasks' tab. | A 'start' button is shown. | The task '*plan mission*' is added to the 'my tasks' list of Albert. | DR7 | |
| | eP | A | Albert's ePartner asks if he wants to perform the task. | | A question 'You have a new task, do you want to start it?' | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | eP | Albert agrees (by clicking the 'start' button). | | appears. | | See next step. | | | |
| 00060 | eP | eP | The task window that corresponds to the task "plan mission" pops up. | R006 (EFF) R023 (EFS, SAT) | | | Details of the task *plan mission* are shown. | | | 2 |
| | eP | eP | The purpose of this screen is to fill in the remaining *TaskParameters.* One task parameter of the process "*Cache construction process*" is *LocationOfCache*. | R024 (EFS) | | | | The system derives the optimal value for parameter *LocationOfCache* (as well as an explanation). | DR10 | |
| | eP | A | ePartner shows best location on mission planning screen. With explanation why this location is good (lighting, risk of dangerous weather is low, shelter quality is good etc.). | | A question 'This would be a good location. Do you agree?' appears. | | Optimal value for parameter *LocationOfCache* is shown, along with corresponding explanation. | | | |
| | A | eP | Albert agrees (by clicking 'Yes'). | | | | | Optimal value is assigned to parameter *LocationOfCache*. | OR3 | |
| 00070 | eP | eP | ePartner suggest route. | R031 (CTL, EFS) | | | Optimal route is shown. | The system calculates the optimal route. | DR12 | 3 |
| | eP | A | ePartner asks if the route is OK. | | A question 'I suggest to take this route. Do you agree?' appears. | | | | | |
| | A | eP | Albert agrees (by clicking 'Yes'). | | | | | Proposed route is confirmed. | OR3 | |
| 00080 | eP | eP | ePartner asks which resources will be allocated to the process. | R021, R020, R007 (EFY, HME, EFS) | | | | The system derives the optimal values for the resources required by the 4 tasks in the '*cache construction process*'. | DR13 | 4,5 |
| | eP | A, H | ePartner does a proposal: Albert and Rover1 will go on EVA, the cache and 2 large drills will be taken as inventory, five batteries and five oxygen containers as cache payload as well as | | A question 'Validate the allocation of resources to the tasks' appears. | | Optimal values for resources are shown. | | | |
| | | | | | | | See next step. | Proposed values for resources are confirmed. | OR4 | |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | mission time are allocated to the cache set-up mission phases . | | | | | | | |
| | A, H | eP | Validate proposed resource allocation (by clicking 'Validate'). | | | | | | | |
| 00090 | A, H | eP | Accept suggested schedule and inventory overview (by clicking 'Yes'). | | A question 'Save the mission parameters?' appears. | | A summary of all mission parameters is shown. | See next step. | | 4,5 |
| | A | eP | Confirm saving of mission parameters (by clicking 'Yes'). | | | | | | | |
| 00100 | eP | eP | | R059<br>R045 (HME, SAW)<br>R038 (EFS, HME)<br>R036 (EFS) | | | | The system concludes that the function '*maintain safety*' is compromised, because no process is deployed that fulfils it. | PR1 | 4,5 |
| | eP | A | ePartner shows the functional screen and notifies Albert that the safety function is not realized. | | A warning 'The function maintain safety is compromised!' appears. | The functions tab is shown, which contains two functions, '*construction*' and '*maintain safety*'. The first function is shown in green, the second one in red. | Details of the function '*maintain safety*' are shown, indicating that this function is compromised. | | NR1<br>DR9<br>OR2 | |
| 00105 | eP | A | ePartner suggests to add a safety monitoring procedure. | R039 (EFS, HME, CRS) | A question 'Do you want to add processes for ensuring safety?' appears. | See next step. | See next step. | The system derives that adding a process '*monitor mission from habitat*' solves the problem. | DR9 | 4,5 |
| | A | eP | Albert agrees (by clicking 'Yes'). | | See next step. | | | The process is added, which means that its status changes to 'deployed'. | OR2 | |
| 00110 | eP | A | ePartner shows the added process | R014<br>R027 (EFS) | A message 'The process has been deployed!' appears. | The processes tab is shown, indicating that two processes (*cache construction process* and *monitor mission from habitat*) are currently deployed. | Details of the process '*monitor mission from habitat*' are shown. | The function '*maintain safety*' is not compromised anymore. | PR1 | 4,5 |

**Table 6: Stepwise Decomposition of Design Scenario (with ePartner) Phase 1**

| Step | A | T | Action | Reqs | Effect left tab (ECA) | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Rules required | Outline Step |
|---|---|---|---|---|---|---|---|---|---|---|
| *Phase 2a: Clearing the surface – off-nominal condition (with ePartner)* | | | | | | | | | | |
| 02000 | A | R1 | Load supplies onto rover and mount it | | | | | | | 6 |
| 02005 | H | eP | Hannah logs in on her device with a *username* and *password,* thereby gaining access to the up-to date knowledge base with all information relevant to the cache set-up mission | | | | | | | 6 |
| 02010 | A, R1 | eP | Drive Rover1 to planned location. | R027 (EFS) | A message 'Task *plan mission* has been completed' appears. | Depends on the tab that is selected. | Details are shown of a particular function, process, task or resource (depends on user choice). | The status of the task '*plan mission*' becomes *finished*, and that of the task '*drive to location*' becomes *busy*. | OR15 | 6 |
| 02020 | H | eP | Monitor processes relevant for EVA (rover status, Albert status, planning, schedule for task) on resource screen (map view, table view), and process screen. | R013 (EFS) R003 (AUT, EFY,SAF, EMO, SAT) R010 (EFS, SAT) R004 (SAW) R002 (EFF, SAW) | | Depends on the tab that is selected. | Depends on the tab that is selected. | | | 7 (14) |
| 02030 | eP<br><br>eP<br><br><br><br>eP | eP<br><br>eP<br><br><br><br>A, H | Problem with Rover1 (one of the wheels is turned in a different angle compared to the other three, off by a slight angle of a few degrees) | R005 (EFS, SAF, SAT) R010 (EFS, SAT) R027 (EFS) R015(HME) R016 (HME, SA) | A warning 'The tasks drive to location and return to habitat have insufficient resources!' appears. | The my tasks tab is shown, where the tasks '*drive to location*' and '*return to habitat*' are shown in red. | Details of the tasks '*drive to location*' and '*return to habitat*' are shown, indicating that these tasks have insufficient resources. | The wheel status of Wheel 1 has changed.<br>The status of the tasks '*drive to location*' and '*return to habitat*' becomes *insufficientResources*. | <br>PR2<br><br><br><br>NR2 | 8,9 |
| 02040 | eP | A, H | Since the malfunctioning wheel is expected to cause a higher load on the battery, several alternatives are evaluated by the ePartner and presented in a | R017 (EFS, EFY, HME) R030 (HME) R032 (EFY, EFS) | | | | | | 10 |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | "team huddle" to both Albert and Hannah. This can be alternatives like:<br>• Following the original plan runs the risk of having to abandon the rover, having to walk back to the habitat and loose valuable mission time for recovering the rover<br>• Aborting the mission and directly returning to the habitat also loses mission time<br><br>• Setting up the cache closer to the habitat reduces the benefit of the cache (extending the range of the traverse), also adversely affecting mission objecttives<br><br>• A creative solution that minimizes the impact could be to use one of the batteries foreseen for the cache to replace the one that may fail on the journey back due to the additional drain. | | A question 'Which option do you want to execute?' appears. | A list of all alternative options appears (along with additional explanation about the predicted effect of these options!), from which the user can select one. | | The option of aborting the mission is generated.<br><br>The option of changing the value of task parameter '*LocationOfCache*' is generated.<br><br>The option of allocating Battery2 (instead of Battery1) to the task '*return to habitat*' is proposed. | DR8<br><br>DR11<br><br>DR14 | |
| 02045 | A, H | eP | Decide to go with option to replace the battery. The process 'battery exchange' is added (by ePartner) | R025 (EFS)<br>R027 (EFS) | A message 'The process has been deployed!' appears. | The task *'change battery'* becomes available. | | | | 11 |
| 02050 | A, H | eP | The plan is updated by adding the battery exchange activity. To best balance time, oxygen and energy | HEART-028<br>R024 (EFS)<br>R014<br>R033 (EFY) | | The process tab is shown, in which the *'cache construction process'* is highlighted. | Details of the process *'cache construction process'* are shown. Now, instead of the original sequence of 4 tasks, it | Proposal to use Battery2 for the task '*return to habitat*' is confirmed, and an additional task '*change battery*' is added to the | OR5 | 11 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | margins, the exchange activity is scheduled to be performed on arrival at the cache site. | | | | also contains the additional task '*change battery*'. | *'cache construction process'*, right after '*drive to location*'. | | |
| 02070 | H | | Monitor processes relevant for EVA (rover status, Albert status, planning, schedule for task) on process and resource screen | R013 (EFS) HEART-R003 (AUT, EFY,SAF, EMO, SAT) R010 (EFS, SAT) R004 (SAW) R002 (EFF, SAW) | | Depends on the tab that is selected. | Depends on the tab that is selected. | | | 14 |
| 02080 | A, R1 | eP | | R009 (EFY, SAW) R010 (EFS, | | | | The position of Albert and Rover1 have changed. | | 11, 14 |
| | eP | H | Notify Hannah that EVA team has reached the spot for the cache in process screen | SAT) R025 (EFS) R027 (EFS) R002 (EFF, SAW) | A message 'Task *drive to location* has been completed' appears. | | | The status of the task '*drive to location*' becomes *finished*, and that of the task '*change battery*' becomes *busy*. | OR15 | |
| 02090 | eP | eP | Notify Albert to start battery replacement activity, notify Hannah of beginning battery replacement activity | R023 (EFS, SAT) R024 (EFS) | | | | Task '*change battery*' is allocated to role *astronaut EVA*, which is enacted by Albert. | DR3 | 12 |
| | eP | eP | | | | The task *'change battery*' is highlighted in the 'my tasks' tab. | A 'start' button is shown. | The task '*change battery*' is added to the 'my tasks' list of Albert. | DR7 | |
| | eP | A | | | A question 'You have a new task, do you want to start it?' appears. | | | | | |
| | A | eP | Click start button | | | | Details of the task *change battery* are shown. | | | |
| 02100 | A | B1 B2 | Exchange battery | | | Depends on the tab that is selected. | Depends on the tab that is selected. | The status of Battery1 has changed to '*!operational*'. The status of Battery2 has changed to '*operational*'. | | 12 |
| 02110 | A, B1 B2 | eP | Report successful completion of battery exchange activity | R025 (EFS) R027 (EFS) | A message 'Task *change battery* has been completed' appears. | | | The status of the task '*change battery*' becomes *finished*, and that of the task '*clear area*' becomes *busy*. Also, because of the new battery, the status of tasks '*drive to location*' and '*return to habitat*' is | OR15 PR2 | 12 |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | not *insufficientResources* anymore. | | |
| 02115 | eP | A, H | Report successful completion of the process exchange battery. | R027 (EFS) | A message 'Process *exchange battery* has been completed' appears. | | | The status of the process '*exchange battery*' becomes finished. | | 12 |
| 02120 | eP | eP | In process screen delegate moving of rocks on location for cache to ePartner | R023 (EFS, SAT) | | | | Task '*clear area*' is allocated to role *astronaut EVA*, which is enacted by Albert. | DR2 | 13 |
| | eP | eP | | | | The task *'clear area*' is highlighted in the 'my tasks' tab. | A 'start' button is shown. | The task '*clear area*' is added to the 'my tasks' list of Albert. | DR7 | |
| | eP | A | | | A question 'You have a new task, do you want to start it?' appears. | | | | | |
| | A | eP | Confirm start of task | | | | Details of the task *clear area* are shown. | | | |
| 02130 | A, R1 | eP | Assign Rover1 to remove rocks from the location. Eurobot autonomously removes the rocks. | R010 (EFS, SAT) R002 (EFF, SAW) | | Depends on the tab that is selected. | Depends on the tab that is selected. | The position of Albert and Rover1 have changed. | | 13 |
| 02140 | eP | A, H | Notify that location has been cleared of rocks by showing that the EVA is in the next step of the process in process screen. | R025 (EFS) R027 (EFS) | A message 'Task *clear area* has been completed' appears. | The task *'drill holes*' is highlighted in the 'my tasks' tab. | | The status of the task '*clear area*' becomes *finished*, and that of the task '*drill holes*' becomes *busy*. | OR15 | 15, 14 |

**Table 7: Stepwise Decomposition of Design Scenario (with ePartner) Phase 2a**

| Step | A | T | Action | Reqs | Effect left tab (ECA) | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Rules required | Outline Step |
|---|---|---|---|---|---|---|---|---|---|---|
| *Phase 3: Construction (with ePartner)* | | | | | | | | | | |
| 03010 | eP | eP | The workflow automatically activates the next task in the process, namely the construction task. | | See previous step. | See previous step. | | See previous step. | | 16 |
| 03020 | eP | eP | The ePartner receives the task "drilling" | R023 (EFS, SAT) R025 (EFS) | | | | Task '*drill holes*' is allocated to role *electronic assistant*, which is enacted by ePartnerA. | DR4 | 17 |
| | eP | eP | | | | The task *'drill holes*' is highlighted in the 'my tasks' tab. | Details of the task *drill holes* are shown. | The task '*drill holes*' is added to the 'my tasks' list of ePartnerA. | DR7 | |
| 03030 | eP | R1 LD | Configure Rover1 to drill and control Rover1 through robot control unit to drill the holes in desired location | Should Albert help, e.g. equip Eurobot with a drill? Or has that already been mounted before leaving? R010 (EFS, SAT) | | Depends on the tab that is selected. | Depends on the tab that is selected. | The status of Rover1 and LargeDrill have changed to '*operational*'. | | 17 |
| 03040 | eP | A | Show in process screen that the drilling has finished | R025 (EFS) R027 (EFS) | A message 'Task *drill holes* has been completed' appears. | | | The status of the task '*drill holes*' becomes *finished*, and that of the task '*unfold cache*' becomes *busy*. | OR15 | 17 |
| 03050 | eP | eP | | | | | | Task '*unfold cache*' is allocated to role *astronaut EVA*, which is enacted by Albert. | DR5 | 18 |
| | eP | eP | | | | The task *'unfold cache*' is highlighted in the 'my tasks' tab. | A 'start' button is shown. | The task '*unfold cache*' is added to the 'my tasks' list of Albert. | DR7 | |
| | eP | A | Notify Albert to start the unfolding cache activity. (Albert confirms clicking on 'start') | | A question 'You have a new task, do you want to start it?' appears. | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 03055 | A | ep | Take cache construction kit out of Rover1 and unfold it | | | | Details of task *unfold cache* are shown. | | | 18 |
| 03057 | ep | A | Report of successful completion of unfolding cache | R025 (EFS)<br>R027 (EFS) | A message 'Task *unfold cache* has been completed' appears. | | See next step. | The status of the task 'unfold cache' becomes *finished*, and that of the task '*fix cache*' becomes busy. | | 18 |
| 03060 | eP<br><br>eP<br><br><br><br>eP | eP<br><br>eP<br><br><br><br>A | Instruct Albert in process screen which pole he has to put where | We could use an instant tent or shelter (quechua) that the participant unpacks and places in the correct position R023 (EFS, SAT) | A question 'This would be a good location for the poles. Do you agree?' appears. | | Details of the task *fix cache* are shown.<br><br><br><br><br><br>Optimal value for parameter *LocationOfCache* is shown. | <br><br>The system derives the optimal value for parameter *Location-OfPoles*. | <br><br>DR10 | 19 |
| 03070 | A | eP | Tick off placed poles on process screen and confirm erection of cache. | | | | | Optimal value is assigned to parameter *Location-OfPoles*.<br>The status of CacheTent has changed to '*operational*'. | OR3 | 19 |
| 03080 | eP | A | When all poles have been placed and cache is in place, display that task has been finished | R025 (EFS)<br>R027 (EFS) | A message 'Task *fix cache* has been completed' appears. | | | The status of the task '*fix cache*' becomes *finished*, and that of the task *'fill cache'* becomes *busy*. | OR15 | 19 |
| 03082 | eP | A | Instruct Albert to fill cache | | A message 'Please fill supplies into cache appears' with request for confirmation | | | | | 19 |
| 03085 | A<br>A | <br>eP | Fill cache with supplies and confirm task completion | R025 (EFS) | | | | The status of the task '*fill cache*' becomes *finished*, and that of the task *'return to habitat'* becomes *busy*. | | 19 |
| 03090 | eP<br><br><br><br>eP | eP<br><br><br><br>eP | | R023 (EFS, SAT) | | The task *'return to habitat'* is highlighted in the 'my tasks' tab. | A 'start' button is shown. | Task '*return to habitat*' is allocated to role *astronaut EVA*, which is enacted by Albert.<br><br>The task '*return to habitat*' is added to the 'my tasks' list of Albert. | DR6<br><br><br><br>DR7 | 19 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | eP<br><br>A | A<br><br>eP | Albert clicks 'ok' | | A question 'You have a new task, do you want to start it?' appears. | | See next step. | | | |
| 03100 | eP | eP | Show next step in process (return to habitat) in process screen | R023 (EFS, SAT) | | | Details of the task *return to habitat* are shown. | | | 19 |

**Table 8: Stepwise Decomposition of Design Scenario (with ePartner) Phase 3**

| Step | A | T | Action | Reqs | Effect left tab (ECA) | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Rules required | Outline Step |
|---|---|---|---|---|---|---|---|---|---|---|
| *Phase 4a: Return to habitat – off-nominal condition (with ePartner)* | | | | | | | | | | |
| 05010 | A | eP | In process screen, select return to habitat phase | | Done in 03080. | Done in 03080. | Done in 03080. | Done in 03080. | Done in 03080. | 20 |
| 05020 | eP | H | Hannah is notified in process screen that Albert is in the next step (return to habitat) | R014 | | The process tab is shown, in which the *'cache construction process'* is highlighted. | All tasks of the process *'cache construction process'* are shown. The task '*return to habitat*' is highlighted. | | | 20 |
| 05030 | eP | eP | Receives information from the robot and sees that all processes are OK | R010 (EFS, SAT) | | Depends on the tab that is selected. | Depends on the tab that is selected. | The *BatteryStatus* of *Battery1* decreases gradually. | | 20 |
| 05040 | eP<br><br><br><br>eP<br><br>eP<br><br>eP<br><br>eP | eP<br><br><br><br>eP<br><br>eP<br><br>eP<br><br>H, A | Show warning in function screen that the communication functionality is not working | R005 (EFS, SAF, SAT)<br>R015(HME)<br>R016 (HME, SA)<br>R045 (HME, SAW)<br>R038 (EFS, HME)<br>R036 (EFS)<br>R046 (HME, SAW) | A warning 'The function *communication* is compromised!' appears. | The functions tab is shown, where the function '*communication*' is shown in red. | Details of the function '*communication*' are shown, indicating the process that is not functioning. | The communication status of *Communication System* becomes *dysfunctional*.<br>The status of the task '*return to habitat*' becomes *dysfunctional*.<br>The status of the '*cache construction process*' becomes *dysfunctional*.<br>The status of the function '*communication*' becomes *compromised*. | OR13<br>OR9<br>OR7<br>NR1 | 21 |
| 05050 | eP | eP | ePartner records data to be sent to the habitat when communication is re-established. | R047 (HME, SAW) | | Depends on the tab that is selected. | Depends on the tab that is selected. | | | 21 |
| 05060 | eP | H | Show predicted location of EVA team on process screen | R023 (EFS, SAT)<br>R049 (HME, SAW) | | The 'my tasks' tab is shown, in which the task *'return to habitat'* is highlighted. | Details of the task *'return to habitat'* are shown, in particular the (estimated) current location. | | | 22 |
| 05100 | eP | A | Explain they can wait here for the communication to restore or travel back and that Hannah is aware of the problem and is awaiting his return in the habitat. The ePartner recommends to travel back. | R032 (EFY, EFS)<br>R030 (HME)<br>R039 (EFS, HME, CRS) | A question 'Do you agree with this option?' appears. | The option of moving on without communication system is proposed. | | The option of moving on without communication system is proposed. | DR16 | 23 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 05110 | A | eP | Agree to continue travelling to habitat (by clicking 'Yes'). | R023 (EFS, SAT) | | The 'my tasks' tab is shown, in which the task *'return to habitat'* is highlighted. | Details of the task *'return to habitat'* are shown, in particular the fact that it does not use any resource for the communication functionality. | Proposal to move on without communication system is confirmed. | OR4 | 24 |
| 05113 | eP | A | ePartner measures a heightened arousal and low valence of Albert | | | | | Arousal of Albert becomes high and Valence becomes low. | | 24 |
| 05115 | eP | A | ePartner provides feedback on the emotional state | | A question 'You seem to feel anxious. Is that correct?' appears. | The 'resources' tab is shown, in which the resource *'Albert'* is highlighted. | Details of *Albert* are shown, in particular his arousal and valence. | *PerformerStatus* of Albert is derived to be *stressed*. | PR3 | 24 |
| 05117 | A | eP | Albert confirms he is feeling anxious (by clicking 'confirm'). | | See next step. | See next step. | See next step. | See next step. | See next step. | 24 |
| 05120 | eP<br><br><br><br><br>A<br><br><br><br>eP | A<br><br><br><br><br>eP<br><br><br><br>R1 | ePartner suggests to take control of Rover1 operation and navigation. Albert confirms this suggestion. | R033 (EFY) | A question 'Do you agree with this option?' appears. | The option to let the ePartner perform task '*return to habitat*' is proposed. | | The option to let the ePartner perform task '*return to habitat*' is proposed.<br><br>Proposal to let the ePartner perform task '*return to habitat*' is confirmed. | DR15<br><br><br><br><br>OR4 | 24 |
| 05125 | eP<br><br><br><br><br>eP | A<br><br><br><br><br>R1 | Rover1 operation and navigation is done by the ePartner. | R023 (EFS, SAT) | | The 'my tasks' tab is shown, in which the task *'return to habitat'* is highlighted. | Details of the task *'return to habitat'* are shown, in particular the fact that it is performed by the ePartner. | The position of Albert and Rover1 has changed. | | 24 |
| 05130 | A | eP | Albert tries to re-establish the connection to the habitat in resource screen | | | The 'resources' tab is shown, in which the resource *'Communication System'* is highlighted. | Details of *Communication System'* are shown, in particular its status. | | | 24 |
| 05140 | eP<br><br><br><br>eP<br><br><br><br>eP | eP<br><br><br><br>eP<br><br><br><br>eP | Notify Albert that communication has been restored | | | | | The communication status of *Communication System* becomes *functional*.<br>The status of the task '*return to habitat*' becomes *functional*.<br><br>The status of the '*cache construction process*' becomes *functional*. | <br><br><br><br>OR12<br><br><br><br>OR8 | 25 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | eP | A | | | A message 'The function *communication* is functional!' appears. | The functions tab is shown, where the function '*communication*' is shown in green. | Details of the function '*communication*' are shown. | The status of the function '*communication*' becomes *functional*. | OR6 | |
| 05150 | eP<br><br>eP | H<br><br>H | Notify Hannah that Albert's communication is restored<br><br>and that Albert was feeling quite stressed about being on EVA without communication | | A message 'The function *communication* is functional!' appears. | The functions tab is shown, where the function '*communication*' is shown in green.<br><br>The 'resources' tab is shown, in which the resource *'Albert'* is highlighted. | Details of the function '*communication*' are shown.<br><br>Details of *Albert* are shown, in particular his arousal and valence. | | | 25 |
| 05160 | H | A | Talk to Albert about return trip | | | Depends on the tab that is selected. | Depends on the tab that is selected. | | | 25 |
| 05170 | A, R1<br>eP | eP<br><br>A, H | Show in process screen that the EVA team has arrived at habitat | R023 (EFS, SAT)<br>R002 (EFF, SAW) | A message 'Task *return to habitat* has been completed' appears. | The 'my tasks' tab is shown, in which the task *'return to habitat'* is highlighted. | Details of the task *'return to habitat'* are shown, in particular the taskrunstate (which is '*finished*'). | The position of Albert and Rover1 have changed.<br>The status of the task '*return to habitat*' becomes *finished*. | OR10 | 25 |
| 05180 | eP | A, H | | R025 (EFS) | A message 'Process *cache construction process* has been completed' appears. | | | The status of the process '*cache construction*' becomes *finished*. | | 25 |

**Table 9: Stepwise Decomposition of Design Scenario (with ePartner) Phase 4a**

# 3 METHOD

## 3.1 DESIGN AND TASK

A within subjects design with two conditions was adopted: the condition without ePartner and with ePartner. In both conditions there was one participant who played a role as part of a team in a scenario based evaluation. The participant conducted the evaluation as Albert, who had to go on EVA with the Rover to set-up a shelter for the cache. The other team member was played by a MECA-HEART member and conducted the evaluation as Hannah, who stayed in the habitat to monitor the mission. The participants performed the scenario with and without ePartner, these conditions were alternated and assigned beforehand.

| | Duration (minutes) | Activity |
|---|---|---|
| | 5 | • Welcome & explanation of purpose<br>• Introduction questionnaire |
| | 25 | • Introduction to Albert's role<br>• Training with tablet<br>• Demonstration of simulated space suit handling<br>• Introduction to Eurobot to the degree required for scenario execution |
| | 25 | Condition 1 (with or without ePartner)<br>• Training with tablet<br>• Scenario execution (observer questionnaire)<br>• Questionnaire after condition 1 |
| | 25 | Condition 2 (with or without ePartner)<br>• Training with tablet<br>• Scenario execution (observer questionnaire)<br>• Questionnaire after condition 2 |
| | 5 | Questionnaire after both conditions |
| | 10 | Opportunity for participants to provide general feedback about MECA/HEART |
| **Total Time** | 100 | |

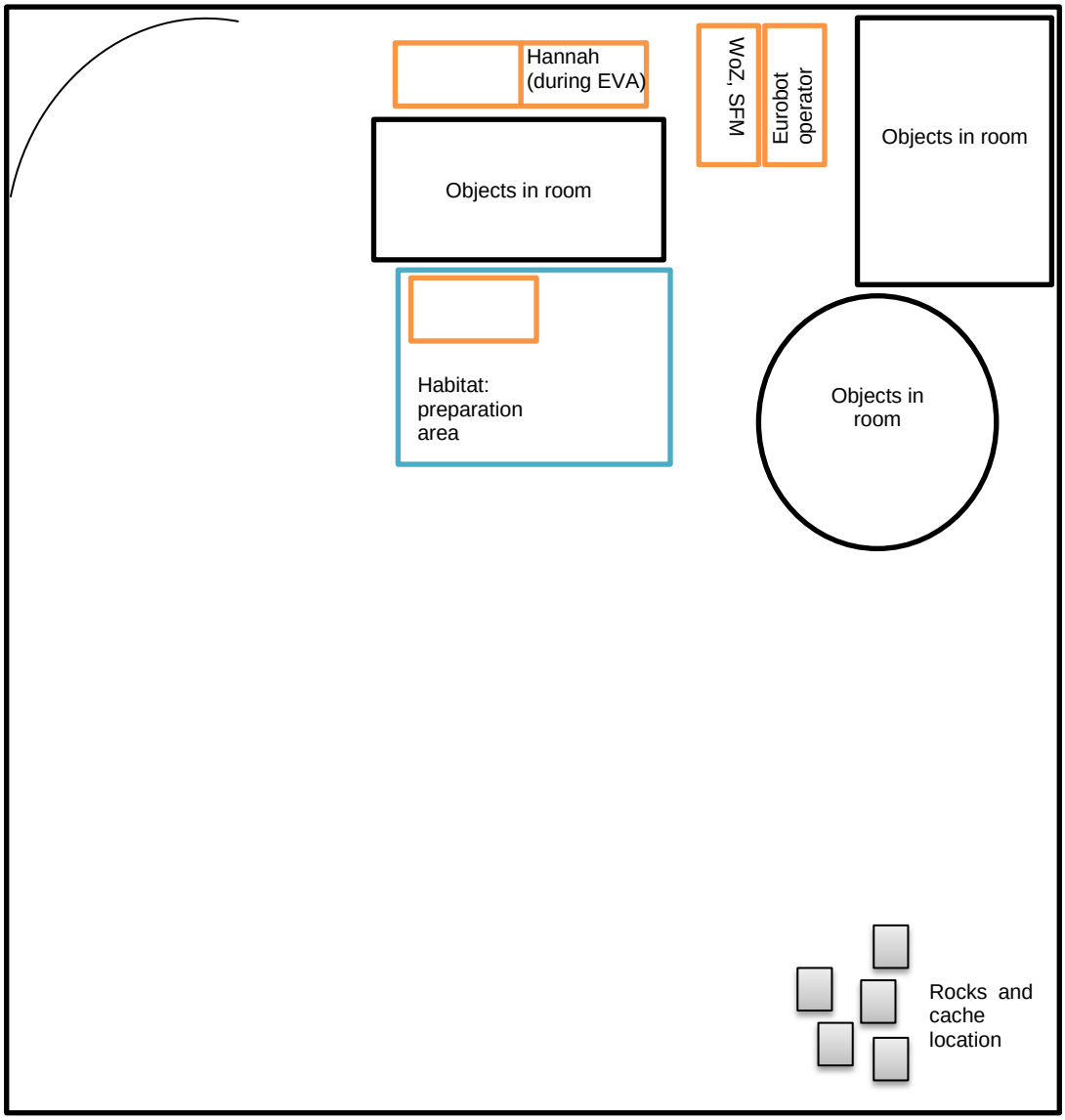
**Table 10: Simulation Session Schedule**

## 3.2 MATERIAL

The device used in the experiment by the participants was a Samsung Galaxy Tab S with Android operating system. The participant, conducting the role of Albert had to perform the EVA with a Rover, in this case this was the Eurobot. List of material needed during experiment:

- Two walkie talkies for communication between Hannah and Albert (participant)
- Five batteries, drill and 'oxygen' tank to load onto Rover and store in cache'
- Pop-up tent to serve as cache

- Two tablets with App software
- WoZ control unit



## 3.3 VARIABLES

In the scenario there are important events where we expected differences between the conditions:

- When communication fails
- Wrong positioned wheel
- Albert stresses
- Failure of safety function for mission is detected with ePartner

## 3.4 DATA COLLECTION

During the experiment we will collect data from various sources, i.e.:

- The low-level interaction logs of the ePartner software (e.g. which tabs are selected, which buttons are clicked etc.)
- The observed behavior and decisions made by the test subjects, i.e. how did they perform their tasks, and how much time did this take. For example, did they change the battery, did they succeed in building the cache, how long did the complete mission take, etc.
- Questionnaires which indicate the subjective experience of using the software.

We will collect the above types of data in the condition with MECA support and without MECA support. Furthermore, we will collect data from expert reviews, which describe the ideal course of events from an arm chair perspective without doing any real experimentation. This allows us to evaluate the MECA prototype against the 13 measures of performance (effectiveness, satisfaction, situation awareness, efficiency, safety, etc.) that have been described in Chapter 5 of D1a. For each of these 13 measures, a comparison will be made between the ideal performance (described by the expert assessment), the condition with MECA support, and the condition without MECA support. As hypothesized in D1a, we expect the performance with MECA to be closer to the ideal performance than the condition without MECA.

# 4 MISSION SIMULATION SCRIPTS

The mission simulation scripts describe the actions on a per-actor basis for each involved human actor. Furthermore timing information is added, covering both simulated mission time (the time to be expect for a real mission) and the experiment time (wall clock time, considerably shorter in order to avoid wasting resources when conducting the experiments). Furthermore, the Wizard of Oz (WOZ) actions are described, which act as a substitute to address limitations of the simulation environment. In particular, due to safety restrictions and technical constraints, no S/W accessible API to the Eurobot system is available. Therefore the WOZ will operate a human mediated interface to the Eurobot to initiate the desired robotic operations and also provide Eurobot related data to the simulation participants. Depending on the progress of the prototype software development activities, WOZ actions may also be required to overcome limitations of the MECA/HEART prototype. Furthermore simulation within the simulation will be required at the mechanical level: In order to not interfere with the Eurobot power system, the battery exchange activity will have to .be performed using substitute hardware. Additionally, some sort of space-suit substitute will be required to make the EVA simulation more realistic.

## 4.1 PROBLEM SCENARIO

The mission simulation scripts for the problem scenario are described by two sets of tables, one for Albert and one for Hannah.

### 4.1.1 MISSION SIMULATION SCRIPT FOR ALBERT

| **Mission Phase 1: *Preliminary preparation*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Albert (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 | M0 | Sit down with Hannah for planning mission, log into device with username and password **(see Step 00010).** | *No Wizard of Oz actions required, basic functionality for mission planning provided by prototype.* | 1 |
| S0 + 00:00:30 | M0 + 00:00:30 | Look up procedures and documentation for related to setting up a cache **(see Step 00020)**. | | 1 |
| S0 + 00:01:00 | M0 + 00:01:00 | Open digital map to look for suitable cache position **(see Step 00025)**. | | 1 |
| S0 + 00:03:00 | M0 + 00:03:00 | Select cache position and ask Albert for confirmation **(see Step 00025)**. | | 1 |

| | | | | |
|---|---|---|---|---|
| S0 + 00:03:30 | M0 + 00:03:30 | Mark route to planned location on map **(see Step 00030)**. | | 2 |
| S0 + 00:04:00 | M0 + 00:04:00 | Schedule operation phases **(see Step 00040)**. | | 3 |
| S0 + 00:04:30 | M0 + 00:04:30 | Look up required inventory and create inventory list. | | 4 |

| | | | | |
|---|---|---|---|---|
| S0 + 00:05:00 | M0 + 00:05:00 | Ask Albert for confirmation on route, schedule and inventory list. | | 4 |

**Table 11: Mission Simulation Script for Albert Phase 1 (Problem Scenario)**

| **Mission Phase 2a: *Approaching site and clearing the surface – off-nominal condition*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Albert (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:07:00 | M0 + 00:07:00 | Put on spacesuit and load cache payload onto rover **(see Step 02000)** | | 5 |
| S0 + 00:08:00 | M0 + 00:08:00 | Take seat/stand on rover **(see Step 02000)** | | 5 |
| S0 + 00:08:30 | M0 + 00:08:30 | Log into handheld device **(see Step 02005)**, command rover to drive to planned location **(see Step 02010)** and notify Hannah on voice loop about departure **(see Step 02010)**. | Use human mediated interface to make Eurobot move.<br>Initiate utility tool to cause gradually decreasing battery level to be displayed.<br>Announce on voice loop to Albert: You are now on your way to the planned cache location. | 5 |
| S0 + 00:10:00 | M0 + 00:45:00 *(Note time warp)* | *No actions yet.* | Inject midcourse location as rover position. | 7 |

| | | | | |
|---|---|---|---|---|
| | | | Use utility tool to adjust displayed battery level to reflect traveled distance (and being gradually decreased further).<br>Announce on voice loop to Albert: Almost three quarters of an hour have passed. You have now made approximately half the way to the cache location.<br>Inject simulated wheel angle deviation to generate corresponding sensor readings.<br>Use human mediated interface to make rover stop. | |
| S0 + 00:10:30 | M0 + 00:45:30 | *Observe FDIR info indicating wheel problem, start of recovery procedure and partial success of that procedure (wheel deviation largely reduced but not completely corrected).* | Use human mediated interface to initiate FDIR simulation. | 8, 9 |
| S0 + 00:11:00 | M0 + 00:46:00 | Discuss problem with Hannah (who checks documentation) and decide to continue mission<br>**(see Step 02040)**. | | 9 |
| S0 + 00:11:30 | M0 + 00:46:30 | Command rover to continue trip to planned cache site<br>**(see Step 02010)**. | Use human mediated interface to make Eurobot move.<br>Initiate utility tool to cause gradually decreasing battery level (now at higher rate) to be displayed. | 9 |
| S0 + 00:14:00 | M0 + 01:35:00 | *No actions yet.* | Inject cache location as rover position.<br>Use utility tool to adjust displayed battery level to reflect traveled distance with increased power consumption.<br>Use human mediated interface to | 10 |

| | | | | |
|---|---|---|---|---|
| | | | make Eurobot stop.<br>Announce on voice loop to Albert: About one and a half hours have passed. You have now reached the cache location. | |
| S0 + 00:14:30 | M0 + 01:35:30 | Notify Hannah on voice loop that cache location has been reached **(see Step 02090)**. | | 11 |
| S0 + 00:15:00 | M0 + 01:36:00 | Look up next activity in agenda documentation<br>**(see Step 0200)** and instruct rover to remove rocks from cache site<br>**(see Step 02120)**. | | 13 |

**Table 12: Mission Simulation Script for Albert Phase 2a (Problem Scenario)**

| **Mission Phase 3: *Construction*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference *(assuming Phase 2a, for Phase 2 subtract 3 minutes)*** | **Simulated Mission Time Reference *(assuming Phase 2a, for Phase 2 subtract 3 minutes)*** | **Actions Albert (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:15:30 | M0 + 01:36:30 | Instruct arm to employ drilling tool and place arm in right location **(see Step 03010)** | | 14 |
| S0 + 00:16:00 | M0 + 01:37:00 | Enter drill depth and instruct robot to create holes. **(see Step 03030)** | Use human mediated interface to make Eurobot drill holes. | 15 |
| S0 + 00:16:30 | M0 + 01:37:30 | Monitor progress of rover, take cache construction kit out of rover and unfold it **(see Step 03050)**. | | 16 |
| S0 + 00:18:00 | M0 + 01:39:00 | Check documentation and place poles in holes accordingly **(see Step 03060)**. | | 17 |
| S0 + 00:18:30 | M0 + 01:39:30 | Fill cache with supplies **(see Step 3085)**. | | 17 |

**Table 13: Mission Simulation Script for Albert Phase 3 (Problem Scenario)**

| **Mission Phase 4a: *Return to habitat – off-nominal condition (battery depletion)*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference *(based on Phase 2a)*** | **Simulated Mission Time Reference *(based on Phase 2a)*** | **Actions Albert (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:20:00 | M0 + 01:41:00 | Notify Hannah that cache construction task is completed and trip back to habitat can begin **(see Step 05010)**. | | 18 |
| S0 + 00:20:30 | M0 + 01:41:30 | Agree with Hannah to begin trip back **(see Step 05030)**.. | | 18 |
| S0 + 00:21:00 | M0 + 01:42:00 | Mount rover and command it to drive back to habitat **(see Step 05040)**. | Use human mediated interface to make Eurobot move.<br>Use human mediated interface to specify power consumption according to wheel offset (Phase 2a).<br>Announce on voice loop to Albert: You are now on your way back to the habitat. | 18 |
| S0 + 00:23:00 | M0 + 02:45:00 *(Note time warp)* | *No particular action* **(see Step 05050)** | Inject position corresponding to travel time.<br>Use utility tool to adjust battery level to traveled distance and power consumption according to wheel offset (Phase 2a).<br>Use human mediated interface to make rover stop.<br>Announce on voice loop to Albert: About one hour has passed. You are about 4 kilometers away from the habitat. | 19 |

| | | | | |
|---|---|---|---|---|
| S0 + 00:23:30 | M0 + 02:45:30 | Notify Hannah on voice loop about beginning of walk back to habitat, dismount rover and start walking **(see Step 05100)**. | | 20 |
| S0 + 00:25:00 | M0 + 03:45:00 | Arrive at habitat and notify Hannah on voice loop about arrival **(see Step 05170)**. | Announce on voice loop to Albert: About one hour has passed. You are now back at the habitat. | 20 |

**Table 14: Mission Simulation Script for Albert Phase 4a (Problem Scenario)**

| **Mission Phase 4b: *Return to habitat – off-nominal condition (communication problem)*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference *(based on Phase 2)*** | **Simulated Mission Time Reference *(based on Phase 2)*** | **Actions Albert (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:17:00 | M0 + 01:38:00 | Notify Hannah that cache construction task is completed and trip back to habitat can begin **(see Step 06010)**. | | 18 |
| S0 + 00:17:30 | M0 + 01:38:30 | Agree with Hannah to begin trip back **(see Step 06030)**.. | | 18 |
| S0 + 00:18:00 | M0 + 01:39:00 | Mount rover and command it to drive back to habitat **(see Step 06035)**. | Use human mediated interface to make Eurobot move.<br>Use human mediated interface to specify power consumption according to nominal conditions (Phase 2).<br>Announce on voice loop to Albert: You are now on your way back to the habitat. | 18 |
| S0 + 00:21:00 | M0 + 02:45:00 *(Note time warp)* | *No particular action* **(see Step 06050)** | Use utility tool to adjust battery level to traveled distance and nominal rover condition (Phase 2) | 19 |

| | | | | |
|---|---|---|---|---|
| | | | Announce on voice loop to Albert: About one hour has passed. You are approximately 4 kilometers away from the habitat.<br>Inject communication failure to trigger corresponding alarm message to be raised. | |
| S0 + 00:21:30 | M0 + 02:45:30 | Continue trip back to habitat with limited communication and navigation capabilities<br>**(see Step 6100)**. | | 20 |
| S0 + 00:23:00 | M0 + 03:20:00<br>*(Note time warp)* | | Inject habitat position.<br>Use utility tool to adjust battery level to traveled distance and nominal rover condition (Phase 2)<br>Announce on voice loop to Albert: About half an hour has passed. You have now reached the habitat.<br>Use human mediated interface to make Eurobot stop. | 20 |

**Table 15: Mission Simulation Script for Albert Phase 4b (Problem Scenario)**

### 4.1.2 MISSION SIMULATION SCRIPT FOR HANNAH

| **Mission Phase 1: *Preliminary preparation*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Hannah (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 | M0 | Sit down with Albert for planning mission **(see Step 00010).** | *No Wizard of Oz actions required, basic functionality for mission planning provided by prototype.* | 1 |
| S0 + 00:03:00 | M0 + 00:03:00 | Agree to Albert's proposal for cache location **(see Step 00025)**. | | 1 |
| S0 + 00:05:00 | M0 + 00:05:00 | Agree to suggested schedule, inventory overview and cache payload **(see Steps 00030, 0040, 0050)**. | | 2,3,4 |

**Table 16: Mission Simulation Script for Hannah Phase 1 (Problem Scenario)**

| **Mission Phase 2: *Approaching site and clearing the surface – nominal condition*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Hannah (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:08:30 | M0 + 00:08:30 | Begin keeping track of camera feeds and monitoring rover data for trip to cache location **(see Step 01020)**. | Use human mediated interface inject corresponding video and telemetry data. | 6 |
| S0 + 00:12:00 | M0 + 01:31:00 *(Note time warp)* | Begin keeping track of camera feeds and monitoring rover data for rock removal **(see Step 01070)**. | Use human mediated interface inject corresponding video and telemetry data. | 9 |

**Table 17: Mission Simulation Script for Hannah Phase 2 (Problem Scenario)**

| **Mission Phase 2a: *Approaching site and clearing the surface – off-nominal condition*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Hannah (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:08:30 | M0 + 00:08:30 | Begin keeping track of camera feeds and monitoring rover data for trip to cache location **(see Step 01070)**. | Use human mediated interface inject corresponding video and telemetry data. | 6 |
| S0 + 00:11:00 | M0 + 00:46:00 *(Note time warp)* | Discuss failed complete wheel recovery problem with Albert. Look up documentation and confirm Albert's suggestion to continue mission. **(see Step 02040)**. | | 9 |

| | | | | |
|---|---|---|---|---|
| S0 + 00:15:00 | M0 + 01:36:00<br>*(Note time warp)* | Begin keeping track of camera feeds and monitoring rover data for rock removal<br>**(see Step 02115)**. | Use human mediated interface inject corresponding video and telemetry data. | 11 |

**Table 18: Mission Simulation Script for Hannah Phase 2a (Problem Scenario)**

| **Mission Phase 3: *Construction*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference *(assuming Phase 2a, for Phase 2 subtract 3 minutes)*** | **Simulated Mission Time Reference *(assuming Phase 2a, for Phase 2 subtract 3 minutes)*** | **Actions Hannah (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:16:30 | M0 + 01:37:30 | Begin keeping track of camera feeds and monitoring rover data for drilling<br>**(see Step 03055)**. | Use human mediated interface inject corresponding video and telemetry data. | 16 |

**Table 19: Mission Simulation Script for Hannah Phase 3 (Problem Scenario)**

| **Mission Phase 4: *Return to habitat – nominal condition*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference *(based on Phase 2)*** | **Simulated Mission Time Reference *(based on Phase 2)*** | **Actions Hannah (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:17:30 | M0 + 01:38:30 | Check robot data and determine that battery level is sufficient for trip back to habitat **(see Step 04030)**. | Use human mediated interface to specify power consumption according to nominal conditions (phase 2). | 18 |
| S0 + 00:18:00 | M0 + 01:39:00 | Begin keeping track of camera feeds and monitoring rover data for trip back to habitat **(see Step 04060)**. | Use human mediated interface inject corresponding video and telemetry data. | 19 |

**Table 20: Mission Simulation Script for Hannah Phase 4 (Problem Scenario)**

| **Mission Phase 4a: *Return to habitat – off-nominal condition (battery depletion)*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference *(based on Phase 2a)*** | **Simulated Mission Time Reference *(based on Phase 2a)*** | **Actions Hannah (see Chapter 2.2.1 for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:20:30 | M0 + 01:41:30 | Check robot data and determine that battery level is sufficient for trip back to habitat **(see Step 05030)**. | Use human mediated interface to specify power consumption according to wheel offset (phase 2a). | 18 |
| S0 + 00:21:00 | M0 + 01:42:00 | Begin keeping track of camera feeds and monitoring rover data for trip back to habitat **(see Step 05045)**. | Use human mediated interface inject corresponding video and telemetry data. | 18 |

**Table 21: Mission Simulation Script for Hannah Phase 4a (Problem Scenario)**

| **Mission Phase 4b: *Return to habitat – off-nominal condition (communication problem)*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference *(based on Phase 2)*** | **Simulated Mission Time Reference *(based on Phase 2)*** | **Actions Hannah (see Chapter** Error! Reference source not found. **for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter 2.1.3)** |
| S0 + 00:17:30 | M0 + 01:38:30 | Check robot data and determine that battery level is sufficient for trip back to habitat **(see Step 06030)**. | Use human mediated interface to specify power consumption according to nominal conditions (phase 2). | 18 |
| S0 + 00:18:00 | M0 + 01:39:00 | Begin keeping track of camera feeds and monitoring rover data for trip back to habitat **(see Step 06037)**. | Use human mediated interface inject corresponding video and telemetry data. | 18 |

**Table 22: Mission Simulation Script for Hannah Phase 4b (Problem Scenario)**

## 4.2 Design Scenario

The mission simulation scripts for the design scenario are described by two sets of tables, one for Albert (and his ePartner) and one for Hannah (and her ePartner).

### 4.2.1 MISSION SIMULATION SCRIPT FOR ALBERT

| **Mission Phase 1: *Preliminary preparation*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Albert (see Chapter 2.2.2 for step references)** | **Actions ePartner Albert (see Chapter 2.2.2 for step references)** | **Actions WOZ** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 | M0 | Sit down with Hannah for mission preparation and provide credentials to ePartner. **(see Step 0010)** | *No particular action yet* | *No Wizard of Oz actions required, functionality for mission planning provided by prototype.* | 1 |
| S0 + 00:00:05 | M0 + 00:00:05 | Request to work on processes **(see Step 0020)** | Offer available options (including adding of new process) and (initially empty) list of processes **(see Step 0020)** | | 1 |
| S0 + 00:00:10 | M0 + 00:00:10 | Request to add new process **(see Step 0020)** | Provide list of available processes and request for selection **(see Step 0025)** | | 1 |
| S0 + 00:00:15 | M0 + 00:00:15 | Select ‘cache construction’ process **(see Step 0030)** | Highlight ‘cache construction process and provide process related details **(see Step 0030)** | | 1 |
| S0 + 00:00:20 | M0 + 00:00:20 | Request deployment of ‘cache construction’ process | Display ‘cache construction’ process as deployed and highlight | | 1 |

| | | | | | |
|---|---|---|---|---|---|
| | | **(see Step 0040)** | initial task 'plan mission' **(see Step 0040)** | | |
| S0 + 00:00:25 | M0 + 00:00:25 | *No particular action yet* | Allocate 'plan mission' task to mission commander Hannah and ask for confirmation **(see Step 0050)** | | 1 |
| S0 + 00:00:30 | M0 + 00:00:30 | Confirm task allocation **(see Step 0050)** | Show task related details, including optimal cache location with supporting information and ask for confirmation of cache location **(see Step 0060)** | | 1, 2 |
| S0 + 00:01:00 | M0 + 00:01:00 | Confirm suggested cache location **(see Step 0060)** | Show optimal route to cache location and ask for confirmation **(see Step 0070)** | | 2,3 |
| S0 + 00:01:30 | M0 + 00:01:30 | Confirm suggested route **(see Step 0070)** | Show proposal for allocation of process resources (Albert, Rover1, cache and two large drills as inventory, required mission time) to mission phases and ask for confirmation **(see Step 0080)** | | 3,4,5 |
| S0 + 00:02:00 | M0 + 00:02:00 | Confirm suggested schedule and inventory **(see Step 0090)** | Show mission parameter summary and request saving them **(see Step 0090)** | | 4,5 |
| S0 + 00:02:05 | M0 + 00:02:05 | Confirm saving of mission parameters **(see Step 0090)** | Indicate missing safety function **(see Step 0090)**, | | 4,5 |

| | | | | | |
|---|---|---|---|---|---|
| | | | suggest to add process for maintaining safety by performing task of monitoring the mission from the habitat **(see Step 0100)** and ask for confirmation **(see Step 0105)** | | |
| S0 + 00:03:00 | M0 + 00:03:00 | Confirm adding safety ensuring process and task **(see Step 0105)** | Show process overview with cache construction and monitoring process and details of monitoring process **(see Step 0110)** | | 4,5 |

**Table 23: Mission Simulation Script for Albert Phase 1**

| **Mission Phase 2:** ***Approaching site and clearing the surface – nominal condition*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Albert (see Chapter 2.2.2 for step references)** | **Actions ePartner Albert (see Chapter 2.2.2 for step references)** | **Actions WOZ** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:06:00 | M0 + 00:06:00 | Put on spacesuit and load cache payload onto rover **(see Step 01000)** | | | |
| S0 + 00:07:00 | M0 + 00:07:00 | Take seat/stand on rover **(see Step 01000)** | | | |
| S0 + 00:07:15 | M0 + 00:07:15 | Log into ePartner **(see Step 01005)** | Obtain up-to-date cache set-up mission plan from central knowledge base **(see Step 01005)** | | 6 |
| S0 + 00:07:20 | M0 + 00:07:20 | Initiate transition to cache location **(see Step 01010)** | Report 'mission planning' as completed, and 'drive to location' as active **(see Step 01010)** | Use human mediated interface to make Eurobot move.<br>Initiate utility tool to cause gradually decreasing battery level to be displayed.<br>Announce on voice loop to Albert: You are now on your way to the planned cache location. | 6 |
| S0 + 00:10:00 | M0 + 01:30:00 *(Note time warp)* | *No actions yet.* **(see Step 01030)** | Report 'drive to location' as completed **(see Step 01040**) | Inject cache location as rover position.<br>Use utility tool to adjust | 8,9 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | displayed battery level to reflect traveled distance (and being gradually decreased further).<br>Use human mediated interface to make Eurobot stop.<br>Announce on voice loop to Albert: Almost one and a half hours have passed. You have now reached the cache location. | |
| S0 + 00:10:05 | M0 + 01:30:05 | *No actions yet.*<br>**(see Step 01050)** | Report 'clear area' as active, point it out as a new task and ask Albert for confirmation to initiate it.<br>**(see Step 01050)** | | 9 |
| S0 + 00:10:10 | M0 + 01:30:10 | Initiate 'clear area'<br>**(see Step 01050)** | Show details related to 'clear area'<br>**(see Step 01050)** | Use human mediated interface to make Eurobot move to rocks. | 9 |
| S0 + 00:10:15 | M0 + 01:30:15 | *No particular actions*<br>**(see Step 01060)** | *No particular actions*<br>**(see Step 01060)** | Use human mediated interface to make Eurobot remove rocks.<br>Inject 'clear area' completion information. | 9 |
| S0 + 00:12:00 | M0 + 01:32:00 | *No particular actions*<br>**(see Step 01070)** | Report 'clear area' as completed, 'drill hole' as active<br>**(see Step 01070)** | | 10, 11 |

**Table 24: Mission Simulation Script for Albert Phase 2**

| **Mission Phase 2a:** ***Approaching site and clearing the surface – off-nominal condition*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Albert (see Chapter 2.2.2 for step references)** | **Actions ePartner Albert (see Chapter 2.2.2 for step references)** | **Actions WOZ** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:06:00 | M0 + 00:06:00 | Put on spacesuit and load cache payload onto rover **(see Step 02000)** | | | |
| S0 + 00:07:00 | M0 + 00:07:00 | Take seat/stand on rover **(see Step 02000)** | | | |
| S0 + 00:07:15 | M0 + 00:07:15 | Log into ePartner **(see Step 02005)** | Obtain up-to-date cache set-up mission plan from central knowledge base **(see Step 02005)** | | 6 |
| S0 + 00:07:20 | M0 + 00:07:20 | Initiate transition to cache location **(see Step 02010)** | Report 'mission planning' as completed, and 'drive to location' as active **(see Step 02010)** | Use human mediated interface to make Eurobot move.<br>Initiate utility tool to cause gradually decreasing battery level to be displayed.<br>Announce on voice loop to Albert: You are now on your way to the planned cache location. | 6 |
| S0 + 00:09:00 | M0 + 00:45:00 *(Note time warp)* | *No particular actions.* | *No particular actions* | Inject midcourse location as rover position.<br>Use utility tool to adjust displayed battery level to | 8, 9 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | reflect traveled distance (and being gradually decreased further).<br>Announce on voice loop to Albert: Almost three quarters of an hour have passed. You have now made approximately half the way to the cache location.<br>Inject simulated wheel angle deviation to generate corresponding sensor readings.<br>Use human mediated interface to make rover stop. | |
| S0 + 00:09:05 | M0 + 00:45:05 | *No particular actions.* | Indicate wheel status and implications of wheel problem on tasks to accomplish.<br>**(see Step 02030)** | | 9 |
| S0 + 00:09:10 | M0 + 00:45:10 | *No particular actions.* | Provide solution options (abort mission, change cache location, exchange battery) with mission impact information to Albert.<br>**(see Step 02040)** | | 10 |
| S0 + 00:09:15 | M0 + 00:45:15 | Select battery exchange option.<br>**(see Step 02045)** | Update task list and resource allocation according to selected option.<br>**(see Steps 2045 &** | | 11 |

| | | | | | |
|---|---|---|---|---|---|
| | | | **02050)** | | |
| S0 + 00:09:20 | M0 + 00:45:20 | *No particular actions.* | *No particular actions.* | Use human mediated interface to make rover move again.<br>Use utility tool to adjust decrease of displayed battery level to simulated failure condition. | 11 |
| S0 + 00:12:00 | M0 + 01:35:00<br>*(Note time warp)* | *No actions yet.*<br>**(see Step 02080)** | Report 'drive to location' as completed<br>**(see Step 02080**) | Inject cache location as rover position.<br>Use human mediated interface to make Eurobot stop.<br>Use utility tool to adjust displayed battery level to reflect traveled distance with given failure condition.<br>Announce on voice loop to Albert: About three quarters of an hour have passed. You have now reached the cache location. | 11 |
| S0 + 00:12:05 | M0 + 01:35:05 | *No actions yet.*<br>**(see Step 02090)** | Report 'battery exchange' task as required and request confirmation of task start.<br>**(see Step 02090)** | | 12 |
| S0 + 00:12:10 | M0 + 01:35:10 | Confirm start of 'battery exchange' task.<br>**(see Step 02090)** | Provide details for 'battery exchange' task.<br>**(see Step 02090)** | | 12 |

| | | | | | |
|---|---|---|---|---|---|
| S0 + 00:12:15 | M0 + 01:35:15 | Exchange battery.<br>**(see Step 02100)** | *No particular action.*<br>**(see Step 02100)** | | 12 |
| S0 + 00:14:00 | M0 + 01:37:00 | Confirm completion of battery exchange activity.<br>**(see Step 02110)** | Report 'battery exchange' task as completed.<br>**(see Step 02110)**<br>Report 'battery exchange' process as completed.<br>**(see Step 02115)** | Inject updated battery status info (battery 2 operational, battery 1 no longer in use).<br>Use utility tool to update battery charge level indication and initiate gradual decrease according to still persistent error condition. | 12 |
| S0 + 00:14:05 | M0 + 01:37:05 | *No actions yet.*<br>**(see Step 02120)** | Report 'clear area' as active, point it out as a new task and ask Albert for confirmation to initiate it.<br>**(see Step 02120)** | | 13 |
| S0 + 00:14:10 | M0 + 01:37:10 | Initiate 'clear area'<br>**(see Step 02120)** | Show details related to 'clear area'<br>**(see Step 02120)** | Use human mediated interface to make Eurobot move to rocks. | 13 |
| S0 + 00:16:00 | M0 + 01:39:00 | *No particular actions*<br>**(see Step 02130)** | *No particular actions*<br>**(see Step 02130)** | Use human mediated interface to make Eurobot remove rocks.<br>Inject 'clear area' completion information. | 13 |
| S0 + 00:16:05 | M0 + 01:39:05 | *No particular actions*<br>**(see Step 02140)** | Report 'clear area' as completed, 'drill hole' as active<br>**(see Step 02140)** | | 15 |

**Table 25: Mission Simulation Script for Albert Phase 2a**

| **Mission Phase 3: Construction** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference *(assuming Phase 2a, for Phase 2 subtract 2 minutes)*** | **Simulated Mission Time Reference *(assuming Phase 2a, for Phase 2 subtract 2 minutes)*** | **Actions Albert (see Chapter 2.2.2 for step references)** | **Actions ePartner Albert (see Chapter 2.2.2 for step references)** | **Actions WOZ** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:16:15 | M0 + 01:39:15 | *No particular actions* **(see Steps 03010, 03020)** | Highlight 'drill holes' and show detailed information for task **(see Step 03020)** | | 17 |
| S0 + 00:16:20 | M0 + 01:39:20 | *No particular actions* **(see Step 03030)** | *No particular actions* **(see Step 03030)** | Use human mediated interface to configure rover for drilling and drill holes (possibly simulated).<br>When drilling is finished, inject completion of drilling task information. | 17 |
| S0 + 00:18:00 | M0 + 01:41:00 | *No particular actions* **(see Step 03040)** | Report completion of drilling **(see Step 03040)** | | 17 |
| S0 + 00:18:05 | M0 + 01:41:05 | *No particular actions* **(see Step 03050)** | Report task 'unfold cache' as active and request confirmation to start it. **(see Step 03050)** | | 18 |
| S0 + 00:18:10 | M0 + 01:41:10 | Confirm start of task, dismount rover, take cache construction kit out of rover and unfold it. **(see Step 03055)** Report successful unfolding | Show detailed information for fixing cache **(see Step 03060)** | | 19 |

| | | | | | |
|---|---|---|---|---|---|
| | | **(see Step 3057)** | | | |
| S0 + 00:18:15 | M0 + 01:41:15 | Place poles (possibly simulated), tick off placed poles in ePartner UI. Erect cache and confirm cache construction task completion in ePartner UI. **(see Step 03070)** | *No particular actions* **(see Step 03070)** | | 19 |
| S0 + 00:20:00 | M0 + 01:43:00 | *No particular actions, all poles have finally been marked as placed* **(see Step 03080)** | Report completion of cache fixing task **(see Step 03080)** | | 19 |
| S0 + 00:20:05 | M0 + 01:43:05 | *No particular actions* **(see Step 03090)** | Report task 'return to habitat' as active and request confirmation to start task **(see Step 03090)** | | 19 |
| S0 + 00:20:10 | M0 + 01:43:10 | Mount rover, confirm start of task 'return to habitat' **(see Step 03090)** | Show details of 'return to habitat' **(see Step 03100)** | Use human mediated interface to make rover move. | 19 |

**Table 26: Mission Simulation Script for Albert Phase 3**

| **Mission Phase 4: *Return to habitat – nominal condition*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference *(assuming Phase 2a)*** | **Simulated Mission Time Reference *(assuming Phase 2a)*** | **Actions Albert (see Chapter 2.2.2 for step references)** | **Actions ePartner Albert (see Chapter 2.2.2 for step references)** | **Actions WOZ** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:21:00 | M0 + 01:43:10 | *No particular action* **(see Step 04010)** | *No particular action* **(see Step 04010)** | Announce on voice loop to Albert: You are now on your way back to the habitat | 20 |
| S0 + 00:23:00 | M0 + 02:30:00 *(Note time warp)* | *No particular action* **(see Step 04030)** | *No particular action* **(see Step 04030)** | Announce on voice loop to Albert: Slightly more than three quarters of an hour have passed. You have made good progress on the way to the habitat.<br>Inject position info corresponding to travelled distance.<br>Use utility tool to adjust battery level to traveled distance and given rover condition depending on nominal resp. off-nominal journey to cache location (Phase 2 resp. 2a). | 20 |
| S0 + 00:23:05 | M0 + 02:30:05 | *No particular action* **(see Step 04040)** | Provide information on estimated arrival time and sufficient remaining battery level for safe return, offer explanation on tasks status. | | 21 |
| S0 + 00:25:00 | M0 + 03:15:00 *(Note time warp)* | *No particular action* **(see Step 04070)** | *No particular action* **(see Step 04070)** | Inject habitat position.<br>Use utility tool to adjust | 22 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | battery level to traveled distance and given rover condition depending on nominal resp. off-nominal journey to cache location (Phase 2 resp. 2a). | |
| S0 + 00:25:05 | M0 + 03:15:05 | *No particular action* **(see Step 04070)** | Report task 'return to habitat' as completed and provide corresponding detailed information. **(see Step 04070)** | | 22 |
| S0 + 00:25:10 | M0 + 03:15:10 | *No particular action* **(see Step 04080)** | Report process 'cache construction' as completed. **(see Step 04080)** | Use human mediated interface to make Eurobot stop.<br>Announce on voice loop to Albert: You have now returned to the habitat. Your mission is completed. | 22 |

**Table 27: Mission Simulation Script for Albert Phase 4**

| **Mission Phase 4a: *Return to habitat – off-nominal condition*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference *(assuming Phase 2a)*** | **Simulated Mission Time Reference *(assuming Phase 2a)*** | **Actions Albert (see Chapter 2.2.2 for step references)** | **Actions ePartner Albert (see Chapter 2.2.2 for step references)** | **Actions WOZ** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:21:00 | M0 + 01:43:10 | *No particular action* **(see Step 05010)** | *No particular action* **(see Step 05010)** | Announce on voice loop to Albert: You are now on your way back to the habitat | 20 |
| S0 + 00:23:00 | M0 + 02:30:00 *(Note time warp)* | *No particular action* **(see Step 05030)** | *No particular action* **(see Step 05030)** | Announce on voice loop to Albert: Slightly more than three quarters of an hour have passed. You have made good progress on the way to the habitat.<br>Inject position info corresponding to travelled distance.<br>Use utility tool to adjust battery level to traveled distance and given rover condition depending on nominal resp. off-nominal journey to cache location (Phase 2 resp. 2a).<br>Inject communication interruption. | 20 |
| S0 + 00:23:05 | M0 + 02:30:05 | *No particular action* **(see Step 05040)** | Report failure of communication function and provide corresponding detailed information. | | 21 |
| S0 + 00:23:10 | M0 + 02:30:10 | | Show options (wait or | | |

| | | | | | |
|---|---|---|---|---|---|
| | | | continue journey back to habitat) with explanations and suggest to continue journey back to habitat. **(See Step 5100)** | | |
| S0 + 00:23:15 | M0 + 02:30:15 | Confirm continuing journey back to habitat without communication. **(see Step 05110)** | Confirm continuation of task 'return to habitat', showing detailed information related to that task, highlighting the fact that it can be safely performed with interrupted communication. **(see Step 05110)** | | 24 |
| S0 + 00:23:20 | M0 + 02:30:20 | *No particular action* **(see Step 05113)** | *No particular action* **(see Step 05113)** | Inject heightened arousal and low valence of Albert. | 23 |
| S0 + 00:23:25 | M0 + 02:30:25 | *No particular action* **(see Step 05115)** | Provide feedback on Albert's emotional state and show related detailed information. Ask Albert for level of perceived anxiety. | | 23 |
| S0 + 00:23:30 | M0 + 02:30:30 | Provide feedback on level of anxiety. **(see Step 05117)** | Comfort Albert according to indicated level of anxiety and offer options to either wait or continue journey back to habitat, recommending the latter. **(see Step 05100)** | | 23 |
| S0 + 00:24:00 | M0 + 02:31:00 | *No particular action yet* | Propose taking over navigation and | | 24 |

| | | | | | |
|---|---|---|---|---|---|
| | | **(see Step 05120)** | autonomously perform task 'return to habitat'. | | |
| S0 + 00:24:05 | M0 + 02:31:05 | Confirm proposal to let ePartner take over navigation let ePartner perform task 'return to habitat'. **(see Step 05120)** | Show information on task 'return to habitat', pointing out that it is performed by ePartner. | | 24 |
| S0 + 00:26:00 | M0 + 02:45:00 *(Note time warp)* | *No particular action yet* **(see Step 05130)** | *No particular action yet* **(see Step 05130)** | Inject updated position closer to habitat.<br>Use utility tool to adjust battery level to traveled distance and given rover condition depending on nominal resp. off-nominal journey to cache location (Phase 2 resp. 2a).<br>Announce on voice loop to Albert: You have now traveled almost a quarter of an hour and made good progress towards the habitat. It is a good time to try to re-establish the communication. | 24 |
| S0 + 00:26:05 | M0 + 02:45:05 | Try to re-establish communication. **(see Step 05130)** | Show details on communication system. **(see Step 05130)** | Inject information that communication system has been restored. | 25 |
| S0 + 00:26:10 | M0 + 02:45:10 | *No particular action* **(see Step 05140)** | Report that communication system has become functional again and show updated task and process info. **(see Step 05140)** | | 25 |

| | | | | | |
|---|---|---|---|---|---|
| S0 + 00:27:00 | M0 + 02:45:00 | Reply to Hannah about return trip **(see Step 05160)** | *No particular action* **(see Step 05160)** | | 25 |
| S0 + 00:29:00 | M0 + 03:15:00 *(Note time warp)* | *No particular action* **(see Step 05170)** | *No particular action* **(see Step 05170)** | Inject habitat position.<br>Use utility tool to adjust battery level to traveled distance and given rover condition depending on nominal resp. off-nominal journey to cache location (Phase 2 resp. 2a). | 25 |
| S0 + 00:29:05 | M0 + 03:15:05 | *No particular action* **(see Step 05170)** | Report task 'return to habitat' as completed and provide corresponding detailed information. **(see Step 05170)** Report process 'cache construction' as completed. **(see Step 05180)** | | 25 |
| S0 + 00:29:10 | M0 + 03:15:10 | *No particular action* **(see Step 05180)** | *No particular action* **(see Step 05180)** | Use human mediated interface to make Eurobot stop.<br>Announce on voice loop to Albert: You have now returned to the habitat. Your mission is completed. | 25 |

**Table 28: Mission Simulation Script for Albert Phase 4a**

### 4.2.2 MISSION SIMULATION SCRIPT FOR HANNAH

| **Mission Phase 1: *Preliminary preparation*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Hannah (see Chapter 2.2.2 for step references)** | **Actions ePartner Hannah (see Chapter 2.2.2 for step references)** | **Actions WOZ (limited to voice loop Hannah, data injection & rover control actions described in section for Albert)** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 | M0 | Sit down with Albert for planning mission **(see Step 00010).** | *Hannah's ePartner is not active during planning. It will obtain the planning results when Hannah logs in (Phase 2/2a).* | *No Wizard of Oz actions required, functionality for mission planning provided by prototype.* | 1 |
| S0 + 00:04:00 | M0 + 00:04:00 | Agree to ePartner proposal for cache setup mission and assigned role **(see Step 00080)** as well a suggested schedule, inventory overview and cache payload **(see Step 00090)** and safety provided by monitoring from habitat **(see Step 00110)**. | | | 4,5 |

Table 29: Mission Simulation Script for Hannah Phase 1

| **Mission Phase 2:** ***Approaching site and clearing the surface – nominal condition*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Hannah (see Chapter 2.2.2 for step references)** | **Actions ePartner Hannah (see Chapter 2.2.2 for step references)** | **Actions WOZ (limited to voice loop Hannah, data injection & rover control actions described in section for Albert)** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:07:20 | M0 + 00:07:20 | *No actions yet* **(see Step 01010)** | *No actions yet* **(see Step 01010)** | Announce on voice loop to Hannah: Albert is now on his way to the planned cache location. | 6 |
| S0 + 00:07:25 | M0 + 00:07:25 | Begin monitoring processes relevant for EVA **(see Step 01020)** | Display information to enable monitoring processes relevant for EVA **(see Step 01020)** | | 7 |
| S0 + 00:10:00 | M0 + 01:30:00 *(Note time warp)* | *No particular actions.* **(see Step 01030)** | Report 'drive to location' as completed **(see Step 01040**) | Announce on voice loop to Hannah: Almost one and a half hours have passed. Albert has now reached the cache location. | 8,9 |
| S0 + 00:10:05 | M0 + 01:30:05 | *No particular actions.* **(see Step 01050)** | Report 'clear area' as active **(see Step 01050)** | | 9 |
| S0 + 00:12:00 | M0 + 01:32:00 | *No particular actions* **(see Step 01070)** | Report 'clear area' as completed, 'drill hole' as active **(see Step 01070)** | | 10, 11 |

**Table 30: Mission Simulation Script for Hannah Phase 2**

| **Mission Phase 2a:** ***Approaching site and clearing the surface – off-nominal condition*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Hannah (see Chapter 2.2.2 for step references)** | **Actions ePartner Hannah (see Chapter 2.2.2 for step references)** | **Actions WOZ (limited to voice loop Hannah, data injection & rover control actions described in section for Albert)** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:07:20 | M0 + 00:07:20 | Initiate transition to cache location **(see Step 02010)** | Report 'mission planning' as completed, and 'drive to location' as active **(see Step 02010)** | Announce on voice loop to Hannah: Albert is now on his way to the planned cache location. | 6 |
| S0 + 00:07:25 | M0 + 00:07:25 | Begin monitoring processes relevant for EVA **(see Step 02020)** | Display information to enable monitoring processes relevant for EVA **(see Step 02020)** | | 7 |
| S0 + 00:09:00 | M0 + 00:45:00 *(Note time warp)* | *No particular actions.* | *No particular actions* | Announce on voice loop to Hannah: Almost three quarters of an hour have passed. Albert has now made approximately half the way to the cache location. | 8, 9 |
| S0 + 00:09:05 | M0 + 00:45:05 | *No particular actions.* | Indicate wheel status and implications of wheel problem on tasks to accomplish. **(see Step 02030)** | | 9 |
| S0 + 00:09:10 | M0 + 00:45:10 | *No particular actions.* | Provide solution options (abort mission, change cache location, exchange battery) with | | 10 |

| | | | | | |
|---|---|---|---|---|---|
| | | | mission impact information to Hannah. **(see Step 02040)** | | |
| S0 + 00:09:15 | M0 + 00:45:15 | *No particular actions* | Update task list and resource allocation according to option selected by Albert. **(see Steps 2045 & 02050)** | | 11 |
| S0 + 00:12:00 | M0 + 01:35:00 *(Note time warp)* | *No actions.* **(see Step 02080)** | Report 'drive to location' as completed **(see Step 02080**) | Announce on voice loop to Hannah: About three quarters of an hour have passed. Albert has now reached the cache location. | 11 |
| S0 + 00:12:10 | M0 + 01:35:10 | *No actions* **(see Step 02090)** | Report task 'battery exchange' as active. **(see Step 02090)** | | 12 |
| S0 + 00:14:00 | M0 + 01:37:00 | *No action* **(see Step 02110)** | Report 'battery exchange' task as completed. **(see Step 02110)** Report 'battery exchange' process as completed. **(see Step 02115)** | . | 12 |
| S0 + 00:14:10 | M0 + 01:37:10 | *No action* **(see Step 02120)** | Report 'clear area' as active **(see Step 02120)** | | 13 |
| S0 + 00:16:05 | M0 + 01:39:05 | *No particular actions* **(see Step 02140)** | Report 'clear area' as completed, 'drill hole' as active. **(see Step 02140)** | | 15 |

**Table 31: Mission Simulation Script for Hannah Phase 2a**

| **Mission Phase 3: Construction** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference *(assuming Phase 2a, for Phase 2 subtract 2 minutes)*** | **Simulated Mission Time Reference *(assuming Phase 2a, for Phase 2 subtract 2 minutes)*** | **Actions Hannah (see Chapter 2.2.2 for step references)** | **Actions ePartner Hannah (see Chapter 2.2.2 for step references)** | **Actions WOZ (limited to voice loop Hannah, data injection & rover control actions described in section for Albert)** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:18:00 | M0 + 01:41:00 | *No particular actions* **(see Step 03040)** | Report completion of drilling. **(see Step 03040)** | | 17 |
| S0 + 00:18:05 | M0 + 01:41:05 | *No particular actions* **(see Step 03050)** | Report task 'unfold cache' as active **(see Step 03050)** | | 18 |
| S0 + 00:18:10 | M0 + 01:41:10 | *No particular actions* **(see Step 03055)** Report successful unfolding **(see Step 3057)** | Report task 'unfold cache' as completed, task 'cache fixing' as active **(see Step 03060)** | | 19 |
| S0 + 00:20:00 | M0 + 01:43:00 | *No particular actions, all poles have finally been marked as placed* **(see Step 03080)** | Report completion of cache fixing task **(see Step 03080)** | | 19 |
| S0 + 00:20:05 | M0 + 01:43:05 | *No particular actions* **(see Step 03090)** | Report task 'return to habitat' as active **(see Step 03090)** | | 19 |

**Table 32: Mission Simulation Script for Hannah Phase 3**

| **Mission Phase 4: *Return to habitat – nominal condition*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference *(assuming Phase 2a)*** | **Simulated Mission Time Reference *(assuming Phase 2a)*** | **Actions Hannah (see Chapter 2.2.2 for step references)** | **Actions ePartner Hannah (see Chapter 2.2.2 for step references)** | **Actions WOZ (limited to voice loop Hannah, data injection & rover control actions described in section for Albert)** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:21:00 | M0 + 01:43:10 | *No particular action* **(see Step 04010)** | *No particular action* **(see Step 04010)** | Announce on voice loop to Hannah: Albert is now on his way back to the habitat | 20 |
| S0 + 00:23:00 | M0 + 02:30:00 *(Note time warp)* | *No particular action* **(see Step 04030)** | *No particular action* **(see Step 04030)** | Announce on voice loop to Hannah: Slightly more than three quarters of an hour have passed. Albert has made good progress on the way to the habitat. | 20 |
| S0 + 00:23:05 | M0 + 02:30:05 | *No particular action* **(see Step 04040)** | Provide information on estimated arrival time and sufficient remaining battery level for safe return, offer explanation on tasks status. **(see Step 04040)** | | 21 |
| S0 + 00:25:05 | M0 + 03:15:05 *(Note time warp)* | *No particular action* **(see Step 04070)** | Report task 'return to habitat' as completed and provide corresponding detailed information. **(see Step 04070)** | | 22 |
| S0 + 00:25:10 | M0 + 03:15:10 | *No particular action* **(see Step 04080)** | Report process 'cache construction' as completed. **(see Step 04080)** | Announce on voice loop to Hannah: Albert has now returned to the habitat. The mission is completed. | 22 |

**Table 33: Mission Simulation Script for Hannah Phase 4**

| **Mission Phase 4a: *Return to habitat – off-nominal condition*** | | | | | |
|---|---|---|---|---|---|
| **Wall-clock Time Reference *(assuming Phase 2a)*** | **Simulated Mission Time Reference *(assuming Phase 2a)*** | **Actions Hannah (see Chapter 2.2.2 for step references)** | **Actions ePartner Hannah (see Chapter 2.2.2 for step references)** | **Actions WOZ (limited to voice loop Hannah, data injection & rover control actions described in section for Albert)** | **Design Scenario Outline Step Reference (Chapter 2.1.4)** |
| S0 + 00:21:00 | M0 + 01:43:10 | *No particular action* **(see Step 05010)** | *No particular action* **(see Step 05010)** | Announce on voice loop to Hannah: Albert is now on his way back to the habitat | 20 |
| S0 + 00:23:00 | M0 + 02:30:00 *(Note time warp)* | *No particular action* **(see Step 05030)** | *No particular action* **(see Step 05030)** | Announce on voice loop to Hannah: Slightly more than three quarters of an hour have passed. Albert has made good progress on the way to the habitat. | 20 |
| S0 + 00:23:05 | M0 + 02:30:05 | *No particular action* **(see Step 05040)** | Report failure of communication function and provide corresponding detailed information. | | 21 |
| S0 + 00:23:30 | M0 + 02:30:30 | *No particular action* **(see Step 05060)** | Continuously provide estimates of position of Rover & Albert during communication interruption phase | | 22 |
| S0 + 00:26:10 | M0 + 02:45:10 *(Note time warp)* | *No particular action* **(see Step 05150)** | Report restored communication and level of distress felt by Albert | | 25 |
| S0 + 00:26:30 | M0 + 02:46:30 | Talk to Albert about return trip **(see Step 05160)** | | | 25 |
| S0 + 00:29:05 | M0 + 03:15:05 | *No particular action* | Report task ‘return to | | 25 |

| | | | | | |
|---|---|---|---|---|---|
| | *(Note time warp)* | **(see Step 05170)** | habitat' as completed and provide corresponding detailed information. **(see Step 05170)** Report process 'cache construction' as completed. **(see Step 05180)** | | |
| S0 + 00:29:10 | M0 + 03:15:10 | *No particular action* **(see Step 05180)** | *No particular action* **(see Step 05180)** | Announce on voice loop to Hannah: Albert has now returned to the habitat. His mission and yours are completed. | 25 |

**Table 34: Mission Simulation Script for Hannah Phase 4a**

# 5 EXPERIMENT TEST SUBJECT INSTRUCTIONS FOR SIMULATIONS

The experiment test subject instructions are intended to guide the familiarization of the test participants with the overall scenario and the roles they will play during the simulation runs as well as the hardware and software that they will use for playing their roles.

## 5.1 SIMULATION SCENARIO OVERVIEW

Albert and Hannah are part of a team of six astronauts that have landed on Mars. Their mission is to erect an exploratory cache for supporting future exploratory traverses. For fulfilling this mission they have one of four rovers and the material and tools for building the cache at their disposal. At the beginning of the mission Albert and Hannah are in the habitat. The habitat will be erected at a distance of 12 km from the habitat. Fulfilling the mission from planning to completion will take about three to three and a half hours. This mission is simulated within approximately half an hour, so several time warps occur. The rover is simulated using Eurobot, a robotic technology demonstrator at ESTEC.

## 5.2 INTRODUCTION TO ROLE ALBERT

Albert is responsible for erecting the cache. In order to do this, he has to:

- traverse to the cache location using the assigned rover
- prepare the site as required
- unfold the cache
- drill holes using the assigned rover and place poles
- fix the cache
- and return to the habitat using the assigned rover

### 5.2.1 TOOLS AND S/W UI FOR ALBERT (DESIGN SCENARIO)

The rover looks as follows:

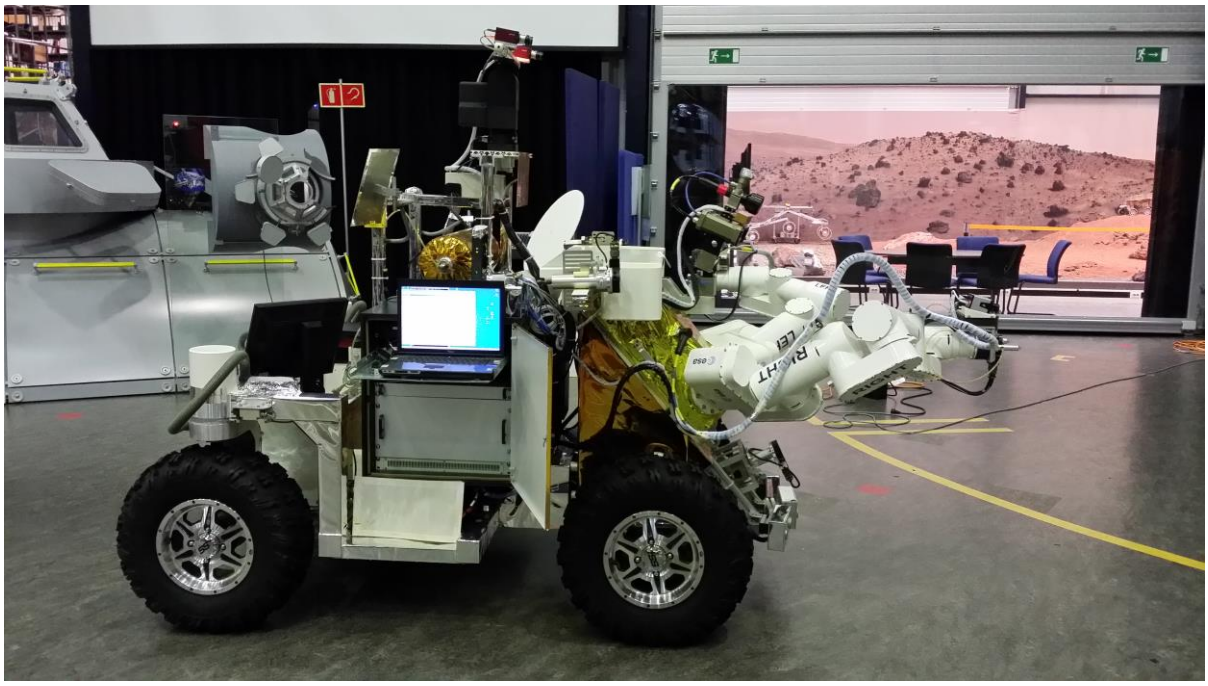


Figure 3: Eurobot

**TBD: Images of simulated spacesuit, cache, drill etc.**

Use of Eurobot, simulated spacesuit, cache, drill etc. will be briefly explained interactively to the participant.

The Software UI for Albert consists of an Android application running on a tablet with large screen. The use of this Software UI is described in [RD1]. It will be briefly explained interactively to the participant with focus on Albert's part of the mission. The following figure gives a first impression of this UI:

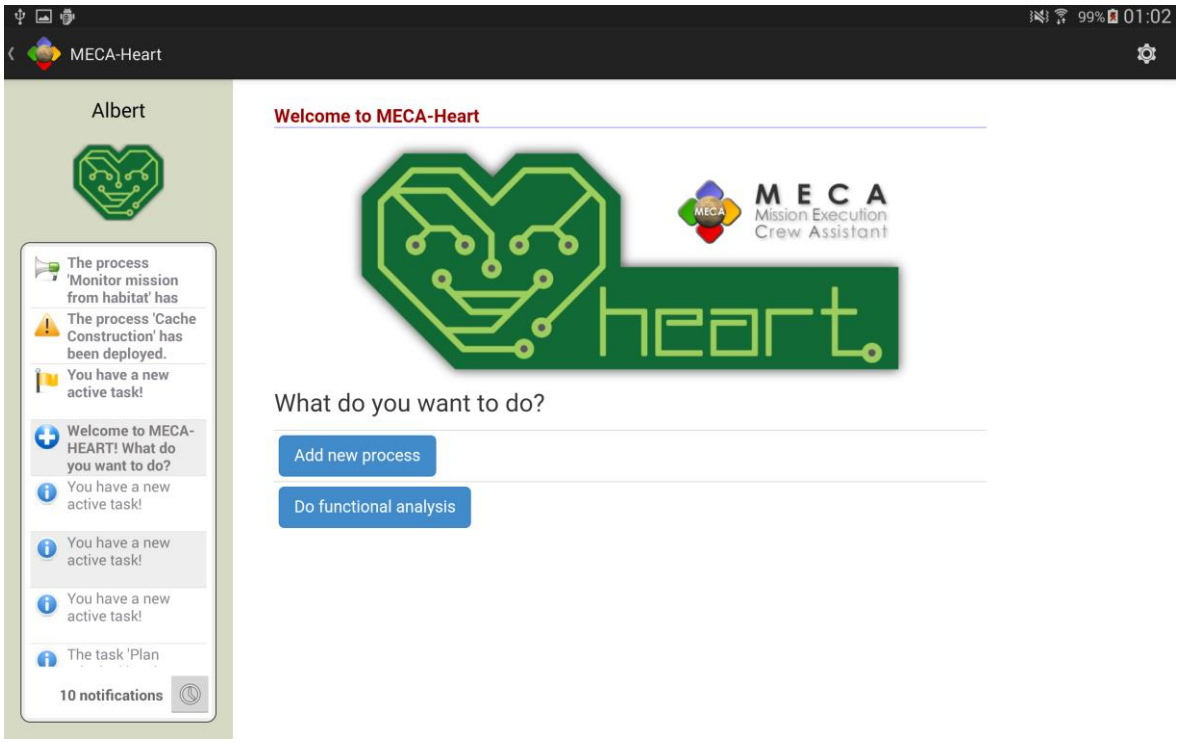



Figure 4: MECA/HEART UI

### 5.2.2 S/W UI FOR ALBERT (PROBLEM SCENARIO)

Rover, cache and other hardware items are identical to the design scenario. The Software UI will be a stripped down version of the one for the design scenario (e.g. Processes and Functions tabs removed). It will be briefly explained interactively to the participant with focus on Albert's part of the mission.

## 5.3 INTRODUCTION TO ROLE HANNAH

Hannah is responsible for planning the cache set-up mission and monitoring it. She remains at the habitat and does not require any hardware tools for performing her job.

### 5.3.1 S/W UI FOR HANNAH (DESIGN SCENARIO)

The Software UI for Hannah consists of an Android application running on a tablet with large screen; similar to the one used by Albert. The use of this Software UI is described in [RD1]. It will be briefly explained interactively to the participant with focus on Hannah's part of the mission.

### 5.3.2 S/W UI FOR HANNAH (PROBLEM SCENARIO)

The Software UI will be a stripped down version of the one for the design scenario (e.g. Processes and Functions tabs removed). It will It will be briefly explained interactively to the participant with focus on Hannah's part of the mission.

# 6 RULES

This chapter contains the complete set of rules used by the inference engine during the scenario. Four sets of rules are distinguished:

- Observability rules (OR)
  - These are rules that serve to update the status of functions, processes, tasks, resources, parameters, etc. This is done either based on user input or based on rules that propagate the status of entities between different levels of the abstraction hierarchy.
- Predictability rules (PR)
  - These are rules that aim to predict the status of various entities (in particular it monitors for compromised tasks and functions). For example, when a resource conflict is identified for a task within a process, the task's field TaskStatus becomes: "InsufficientResources".
- Directability rules (DR)
  - These are rules that serve to allow (human) actors to change the current state of the system. This is done either by allocating tasks to roles, or by proposing certain changes to improve the mission effectiveness (e.g. resource allocations, process changes, etc).
- Notification rules (NR)
  - These are rules that serve to notify the actors of important changes (for example, about a malfunctioning system or a predicted risk).

## 6.1 OBSERVABILITY RULES

### *Processing user input*

**OR1: Confirm process (1)**
***IF*** *Process 'P' has ProcessStatus 'idle'*
***AND*** */* user clicks on 'deployed' for process P */*
***THEN*** *Process 'P' has ProcessStatus 'deployed'*

**OR2: Confirm process (2)**
***IF*** *Process 'Pr' is proposed for Guard 'G'*
***AND*** */* user accepts proposed process Pr */*
***THEN*** *Process 'Pr' has ProcessStatus 'deployed'*

**OR3: Confirm task parameter**
***IF*** *ParValue 'V' is proposed for TaskParameter 'TP'*
***AND*** */* user accepts proposed parameter value V */*
***THEN*** *TaskParameter 'TP' has ParValue 'V'*

**OR4: Confirm resource for task**
***IF*** *Resource 'R' is proposed for Task 'T'*
***AND*** */* user accepts proposed resource R */*
***THEN*** *Task 'T' uses Resource 'R'*

**OR5: Confirm battery replacement**
***IF*** *Task 'T' uses Battery 'B1'*
***AND*** *Battery 'B2' is proposed for Task 'T'*
***AND*** *Process 'P' has Task 'T'*
***AND*** */* user accepts proposed battery B2 */*

***THEN*** *Task 'T' uses Battery 'B2'*
***AND*** *Process 'P' has Task 'replace battery'*
***AND*** */* add battery replace task before Task 'T' */*

## *Setting status of functions, processes and tasks*

**OR6: Set function status to 'functional'**
***IF*** *Function 'F' has Process 'P1' …*
***AND*** *Function 'F' has Process 'Pn'*
***AND*** *Process 'P1' has ProcessStatus 'functional' …*
***AND*** *Process 'Pn' has ProcessStatus 'functional'*
***THEN*** *Function 'F' has FuncStatus 'functional'*

**OR7: Set function status to 'compromised'**
***IF*** *Function 'F' has Process 'P'*
***AND*** *Process 'P' has ProcessStatus 'dysfunctional'*
***THEN*** *Function 'F' has FuncStatus 'compromised'*

**OR8: Set process status to 'functional'**
***IF*** *Process 'P' has Task 'T1' …*
***AND*** *Process 'P' has Task 'Tn'*
***AND*** *Task 'T1' has TaskStatus 'functional' …*
***AND*** *Task 'Tn' has TaskStatus 'functional'*
***THEN*** *Process 'P' has ProcesStatus 'functional'*

**OR9: Set process status to 'dysfunctional'**
***IF*** *Process 'P' has Task 'T'*
***AND*** *Task 'T' has TaskStatus 'dysfunctional'*
***THEN*** *Process 'P' has ProcessStatus 'dysfunctional'*

**OR10: Set process (and task) status to 'finished'**
***IF*** *Process 'P' has ProcessStatus 'deployed'*
***AND*** *Process 'P' has Task 'T'*
***AND*** *Task 'T' is followed by Task 'nil'*
***AND*** */* task T has ended */*
***THEN*** *Task 'T' has TaskRunState 'finished'*
***AND*** *Process 'P' has ProcessStatus 'finished'*

**OR11: Set task status to 'functional'**
***IF*** *Task 'T' has TaskRunState 'busy'*
***AND*** *![Task 'T' has TaskStatus 'insuffResources']*
***THEN*** *Task 'T' has TaskStatus 'functional'*

**OR12: Set task status to 'functional' (2)**
***IF*** *Task 'T' uses Resource 'R1' …*
***AND*** *Task 'T' uses Resource 'Rn'*
***AND*** *Resource 'R1' has Status 'functional' …*
***AND*** *Resource 'Rn' has Status 'functional'*
***THEN*** *Task 'T' has TaskStatus 'functional'*

**OR13: Set task status to 'dysfunctional'**
***IF*** *Task 'T' uses Resource 'R'*
***AND*** *Resource 'R' has Status 'dysfunctional'*
***THEN*** *Task 'T' has TaskStatus 'dysfunctional'*

**OR14: Set task run state to 'busy' (first task)**
***IF*** *Process 'P' has ProcessStatus 'deployed'*
***AND*** *Process 'P' has Task 'T'*
***AND*** */* T is the first task in P with state 'planned' */*
***THEN*** *Task 'T' has TaskRunState 'busy'*

**OR15: Set task run state to 'busy' (next task)**
***IF*** *Process 'P' has ProcessStatus 'deployed'*

***AND*** *Process 'P' has Task 'T1'*
***AND*** *Process 'P' has Task 'T2'*
***AND*** *Task 'T1' is followed by Task 'T2'*
***AND*** */* task T1 has ended */*
***THEN*** *Task 'T1' has TaskRunState 'finished'*
***AND*** *Task 'T2' has TaskRunState 'busy'*

## 6.2 PREDICTABILITY RULES

### *Identifying compromised entities*

**PR1: Identify compromised functions**
***IF*** */* user accepted mission M */*
***AND*** *Mission 'M' has Purpose 'P'*
***AND*** *Purpose 'P' has Value 'V'*
***AND*** *Value 'V' has Function 'F'*
***AND*** *Function 'F' requires Guard 'G'*
***AND*** *Process 'Pr' enacts Guard 'G'*
***AND*** *Process 'Pr' has ProcessStatus 'idle'*
***THEN*** *Function 'F' has FuncStatus 'compromised'*

**PR2: Identify tasks with insufficient battery**
***IF*** *Task 'T' uses Robot 'R'*
***AND*** *Robot 'R' contains Wheel 'W1' …*
***AND*** *Robot 'R' contains Wheel 'W4'*
***AND*** *Wheel 'W1' has WheelStatus 'WS1' …*
***AND*** *Wheel 'W4' has WheelStatus 'WS4'*
***AND*** *WheelStatus 'WS1' uses Wperkm 'x1' …*
***AND*** *WheelStatus 'WS4' uses Wperkm 'x4'*
***AND*** *Robot 'R' contains Battery 'B'*
***AND*** *Battery 'B' has BatteryStatus 'BS'*
***AND*** *BatteryStatus 'BS' has LevelInWatt 'y'*
***AND*** *Task 'T' has TaskParameter 'Distance'*
***AND*** *TaskParameter 'Distance' has ParValue 'd'*
***AND*** *d*(x1+x2+x3+x4) > y*
***THEN*** *Task 'T' has TaskStatus 'insuffResources'*

**PR3: Identify task performer stress**
***IF*** *TaskPerformer 'T' has Emotion.Arousal 'A'*
***AND*** *TaskPerformer 'T' has Emotion.Valence 'V'*
***AND*** *A > 3*
***AND*** *V < 3*
***THEN*** *TaskPerformer 'T' has PerformerStatus 'stressed'*

## 6.3 DIRECTABILITY RULES

### *Allocating tasks*

**DR1: Allocate task 'plan mission'**
***IF*** *Task 'plan mission' has TaskRunState 'busy'*
***AND*** *![Task 'plan mission' is allocated to Role 'R']*
***THEN*** *Task 'plan mission' is allocated to Role 'Mission commander'*

**DR2: Allocate task 'clear area'**
***IF*** *Task 'clear area' has TaskRunState 'busy'*
***AND*** *![Task 'clear area' is allocated to Role 'R']*
***THEN*** *Task 'clear area' is allocated to Role 'astronaut EVA'*

**DR3: Allocate task 'change battery'**
***IF*** *Task 'change battery' has TaskRunState 'busy'*

***AND*** *![Task 'change battery' is allocated to Role 'R']*
***THEN*** *Task 'change battery' is allocated to Role 'astronaut EVA'*

**DR4: Allocate task 'drill holes'**
***IF*** *Task 'drill holes' has TaskRunState 'busy'*
***AND*** *![Task 'drill holes' is allocated to Role 'R']*
***THEN*** *Task 'drill holes' is allocated to Role 'ePartnerA'*

**DR5: Allocate task 'unfold cache'**
***IF*** *Task 'unfold cache' has TaskRunState 'busy'*
***AND*** *![Task 'unfold cache' is allocated to Role 'R']*
***THEN*** *Task 'unfold cache' is allocated to Role 'astronaut EVA'*

**DR6: Allocate task 'return to habitat'**
***IF*** *Task 'return to habitat' has TaskRunState 'busy'*
***AND*** *![Task 'return to habitat' is allocated to Role 'R']*
***THEN*** *Task 'return to habitat' is allocated to Role 'astronaut EVA'*

**DR7: Place task in task list**
***IF*** *Task 'T' has TaskRunState 'busy'*
***AND*** *Task 'T' is allocated to Role 'R'*
***AND*** *TaskPerformer 'TP' enacts Role 'R'*
***THEN*** *Task 'T' is in task list of TaskPerformer 'TP'*

## *Making suggestions to user*

**DR8: Propose aborting mission**
***IF*** *Mission 'M' has Purpose 'P'*
***AND*** *Purpose 'P' has Value 'V'*
***AND*** *Value 'V' has Function 'F'*
***AND*** *Function 'F' requires Guard 'G'*
***AND*** *Process 'Pr' enacts Guard 'G'*
***AND*** *Process 'Pr' has Task 'T'*
***AND*** *Task 'T' has TaskStatus 'insuffResources'*
***THEN*** *Action 'abort' is proposed for Mission 'M'*

**DR9: Propose process for compromised function**
***IF*** *Function 'F' has FuncStatus 'compromised'*
***AND*** *Function 'F' requires Guard 'G'*
***AND*** *Process 'Pr' enacts Guard 'G'*
***THEN*** *Process 'Pr' is proposed for Guard 'G'*

**DR10: Propose task parameter**
***IF*** *Process 'P' has Task 'T'*
***AND*** *Task 'T' has TaskParameter 'TP'*
***AND*** *TaskParameter 'TP' has ParValue 'nil'*
***AND*** */* V is the optimal parameter value for TP */*
***THEN*** *ParValue 'V' is proposed for TaskParameter 'TP'*

**DR11: Propose alternative task parameter**
***IF*** *Task 'T' has TaskStatus 'insufficientResources'*
***AND*** *Task 'T' has TaskParameter 'TP'*
***AND*** *TaskParameter 'TP' has ParValue 'V1'*
***AND*** */* V2 is an alternative value for V1 */*
***THEN*** *ParValue 'V2' is proposed for TaskParameter 'TP'*

**DR12: Propose task parameter 'route'**
***IF*** *TaskParameter 'LocationOfCache' has Value 'L'*
***AND*** */* R is optimal route for location L */*
***THEN*** *Value 'R' is proposed for TaskParameter 'Route'*

**DR13: Propose resource for task**
***IF*** *Process 'P' has Task 'T'*

***AND*** *Task 'T' requires Functionality 'F'*
***AND*** *Resource 'R' provides Functionality 'F'*
***AND*** */* R is the best possible resource */*
***AND*** *![Task 'T' uses Resource 'R']*
***THEN*** *Resource 'R' is proposed for Task 'T'*

**DR14: Propose alternative resource for task**
***IF*** *Task 'T' has TaskStatus 'insufficientResources'*
***AND*** *Task 'T' uses Resource 'R1'*
***AND*** *Task 'T' requires Functionality 'F'*
***AND*** *Resource 'R1' provides Functionality 'F'*
***AND*** *Resource 'R2' provides Functionality 'F'*
***THEN*** *Resource 'R2' is proposed for Task 'T'*

**DR15: Propose alternative resource for task in case of stress**
***IF*** *Task 'T' uses Resource 'R1'*
***AND*** *Resource 'R1' has PerformerStatus 'stressed'*
***AND*** *Task 'T' requires Functionality 'F'*
***AND*** *Resource 'R1' provides Functionality 'F'*
***AND*** *Resource 'R2' provides Functionality 'F'*
***THEN*** *Resource 'R2' is proposed for Task 'T'*

**DR16: Propose empty resource for task**
***IF*** *Task 'T' uses Resource 'R'*
***AND*** *Resource 'R' has Status 'dysfunctional'*
***AND*** *Task 'T' requires Functionality 'F'*
***AND*** *Resource 'R' provides Functionality 'F'*
***AND*** *Resource 'none' provides Functionality 'F'*
***THEN*** *Resource 'none' is proposed for Task 'T'*

## 6.4 NOTIFICATION RULES

### *Generating warnings*

**NR1: Generate warning for compromised functions**
***IF*** *Function 'F' has FuncStatus 'compromised'*
***THEN*** */* warn user about compromised function F */*

**NR2: Generate warning for compromised tasks**
***IF*** *Task 'T' has TaskStatus 'insufficientResources'*
***THEN*** */* warn user about compromised task T */*

# 7 APPENDIX A: REFERENCES

| | |
|---|---|
| RD1 | MECA-HEART WP2 R3A User Manual, Antonio Olmedo Soler, 18 Feb 2015 |
| | |

# 8 APPENDIX B:REQUIREMENTS

| Requirement | | Agent version – step in use case (nominal steps in brackets) | Non-agent version |
|---|---|---|---|
| MECA shall visually represent the current location of actors and resources (HEART-R002) | | In map the current location of actors and resources is represented.<br>02020, 02070, 02080, 02130, 05170<br>(01020, 01030, 01060, 04070) | Electronic map is available with location of actors and resources |
| | MECA shall support crew to decide a location based on given goals and constraints. (HEART-R006) | 00060 | |
| MECA shall monitor the current status of all actors and resources (HEART-R003, questionnaire) | | 00050, 02020, 02070<br>(01020) | Devices monitor own health. |
| | MECA shall monitor the location of a robot while it follows a planned route. (HEART-R009) | Is MECA monitoring the location? Or only representing? Not on Thursday, but there will be a rule for this. | |
| | When the location or status of a resource changes, MECA shall update the information in the inventory. (HEART-R010) | 02020, 02030, 02070, 02080, 02130, 03030, 05030<br>(01020, 01030, 01060, 04030, 04060) | |
| MECA shall represent the current status of all actors and resources (HEART-R004) | | 02020, 02070<br>(01020) | Current status of actors and resources is presented as a list. |
| | MECA shall produce a list of resources necessary for a sequence of tasks, based on the predefined needs and constraints of each task and the availability and status of the resources. (HEART-R007, questionnaire) | 00080 | |
| | MECA shall report on the assignment of resources to scheduled task, blocking | 00050 | |

| | | | |
|---|---|---|---|
| | them for the selected period. (HEART-R008) | | |
| MECA shall raise an alarm when the status of some resource matches a certain condition. (HEART-R005) | | 02030, 05040 | Resources give their own alarms when out-of-bounds. |
| | MECA shall visually represent all planned processes including task ordering, parallelism, resource-allocation, and communications. (HEART-R012) | | |
| | MECA shall propose a schedule, assigning time and duration for each task to be performed by each team member, and assignment of resources. (HEART-R021) | 00080 | |
| | MECA shall provide a global overview of the current situation of each actor and the status of the planned activities. (HEART-R022) | | |
| | MECA shall let the user select a task in the schedule and see details about it. (HEART-R023) | Tasks are shown in the right tab (flow chart) and details and status is available.<br>00060, 02090, 02120, 03020, 03060, 03090, 03100,<br>05060, 05110, 05125, 05170<br>(01050,04040, 04070) | Tasks are shown in the right tab (flow chart). No support as to whether tasks are active or details are not available. |
| | MECA shall guide the user following a sequence of actions to be executed in the right order and providing detailed instructions when the user needs them. (HEART-R024) | 00040, 00060, 02050, 02090<br>(01050) | |
| MECA shall monitor the current status of all processes. (HEART-R013) | | 0220, 02070<br>(0120) | Current status of processes is not monitored. |
| | MECA shall update status of scheduled tasks when user finishes or starts them. (HEART-R025) | 00050, 02045, 02080, 02110, 02140, 03020, 03040, 03057, 03080, 03085, 05180<br>(01010, 01040, 01070, 04070) | |
| | MECA shall log information of executed actions. (HEART-R026) | | |
| MECA shall represent the current status of all processes. (HEART-R014) | | 00030, 00110, 02050, 05020<br>(04020) | Current status of processes is not shown. |

| | | | |
|---|---|---|---|
| | MECA shall report significant change of a task status. (HEART-R027) | 00040, 00110, 02010, 02030, 02045, 02080, 02110, 02115, 02140, 03040, 03057, 03080, (01010, 01040, 01070, 04040, 04070, 04080) | |
| | When a schedule is changed, MECA shall share the changes with those who may be affected. (HEART-R028) | 02050 | |
| | MECA shall update information about the execution of a procedure's step after its completion. (HEART-R029) | | |
| MECA shall detect potential problems in planned processes (HEART-R015) | | 02030, 05040 | Potential problems in planned process are not detected. |
| | MECA shall evaluate impact on planned tasks when resource status change out of planned boundaries (HEART-R030) | 02040, 05100 | |
| | MECA shall calculate time that the robot will take to reach a target point following a certain route. (HEART-R031) | 00070, 04040 | |
| MECA shall alert the user of any problems detected in the planned process. (HEART-R016) | | 02030, 05040 | Problems in planned processes are not detected and thus the user will receive no alerts. |
| MECA shall propose resource reallocations that could solve process-related problems. (HEART-R017) | | 02040 | No resource allocations are proposed. |
| | When the robot fails, MECA shall look for alternative reconfiguration that would allow it completing its task and reaching its goal. (HEART-R032) | 02040 | |
| | When the user gets isolated, MECA shall adapt a rescue procedure based on predefined plans, adapted to the current situation and the estimated status of resources (HEART-R050) | 05100 | |
| MECA shall allow the user to propose resource reallocations (HEART-R018) | | Does the user propose resource reallocations? Task interaction with resources, user can add resources | User can reallocate resources. |

| | | | |
|---|---|---|---|
| | | to forms. | |
| | MECA shall update current schedule based on decisions made by the user. (HEART-R033) | 02050, 05120 | |
| MECA shall be able to commit proposed resource reallocations by collecting acceptance of all stakeholders. (HEART-R019) | | Same question as for R018 | Not applicable. |
| MECA shall monitor the status of each function (HEART-R036) | | 00100, 05040 | |
| | MECA shall monitor the status of communications and detect possible problems. (HEART-R045) | 00100, 05040 | |
| MECA shall alert the user of any functional inadequacy (HEART-R038) | | 00100, 05040 | |
| | MECA shall warn the user when a communication process fails and is not possible to establish direct contact with others. (HEART-R046) | 05040 | |
| MECA shall propose alternative processes (plans) to solve any functional problems (HEART-R039) | | 00105, 05100 | |
| | When communication is interrupted, MECA shall store messages preparing to deliver them when the communication is restored. (HEART-R047) | 05050 | |
| | When communication is restored after an interruption, MECA shall send the stored messages. (HEART-R048) | Cannot find this (see step 05150) | |
| | When direct communication with a monitored actor is lost, MECA shall calculate the possible location. (HEART-R049) | 05060 | |
| MECA shall allow the user to select alternative processes for achieving mission goals. (HEART-R040) | | | |
| | MECA shall accept delegation from user to control a robot. (HEART-R041) | | |
| | MECA shall control a robot, sending commands to ensure that it follows the planned route. (HEART-R042) | | |
| | When the user gets isolated, MECA shall adapt planned actions to be performed without support from others based on the goals and the status of resources. (HEART-R043) | | |
| | MECA shall support decision making process evaluating possible impact of actions on status of resources and probability to fulfill goals. (HEART-R044) | | |
| | MECA shall support crew in decision making process based on given goals and constraints (HEART-R059) | | |

| | | | |
|---|---|---|---|
| MECA shall communicate at the appropriate level of abstraction (HEART-R052) | | | |
| | MECA shall send commands to the robot to change its configuration. (HEART-R057) | | |
| | MECA shall send commands to robot asking to perform planned tasks. (HEART-R058) | | |
| MECA shall suppress any alarms that are subsumed by a higher-level alarm (HEART-R053) | | | |
| MECA shall adapt the level of detail in the resource, process, and functional presentations to its user and the user context. (HEART-R054) | | | |
| MECA shall explain any proposed solutions to the user (HEART-R055) | | | |
| MECA shall support traversing the part-whole relationship (HEART-R056) | | | |

# 9 APPENDIX B: NOMINAL SCENARIO

## 9.1 STEPWISE DECOMPOSITION PROBLEM SCENARIO IN NOMINAL CONDITIONS

| Step | A | T | Action | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Outline Step |
|---|---|---|---|---|---|---|---|
| *Phase 2: Clearing the surface – nominal condition (without ePartner)* | | | | | | | |
| 01000 | A | R1 | Load supplies onto rover and mount it | | | WoZ or automatically: resources are selected and represented as active | 5 |
| 01005 | A | Tablet | Albert logs in on his device with a *username* and *password* | | | | 5 |
| 01010 | A | R1 | Albert gives Rover1 command to drive to planned location. He goes to control of rover screen and pushes button. | | | Status of Rover changes to driving. | 5 |
| | H | A | Albert notifies Hannah he is leaving via voice | | | | 5 |
| 01020 | H | Tablet2 | Hannah keeps track of camera feeds provided by Rover, looks out for alarms and requests sensor data. | | | | 6 |
| 01030 | A, | Tablet | Albert sees that location has been reached. | | | The position of Albert and Rover1 have changed in resources screen. | 7 |
| 01040 | A. | H | By voice Albert confirms to Hannah that he has reached the planned location. | | | | 7 |
| 01050 | A | Tablet | Albert looks in agenda/ documentation what the next step is. | | | | 8 |
| 01060 | A | R1 | Albert instructs Rover to move unwanted rocks out of the selected area. Albert goes to control of rover screen and gives the command. | | | Status of Rover changes to clearing surface. | 8 |
| 01070 | H | Tablet2 | Hannah keeps track of camera feeds provided by Rover, looks out for alarms and requests sensor data. | | | | 9 |
| 01080 | R1 | A,H | Rocks have been removed from area, show current status in process screen. | | | | 10 |

**Table 35: Stepwise Decomposition of Problem Scenario (without ePartner) Phase 2**

| Step | A | T | Action | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Outline Step |
|---|---|---|---|---|---|---|---|
| *Phase 4: Return to habitat – nominal condition (without ePartner)* | | | | | | | |
| 04010 | A | H | Albert communicates that task is completed and he is going back to habitat. | | | | 18 |
| 04030 | H, A | Tablet | Hannah requests sensory data information from robot. Hannah sees that the Rover1 battery level should be enough to get back to the habitat. Hannah and Albert decide to commence journey back to habitat. | | | The *BatteryStatus* of *Battery1* decreases gradually. | 18 |
| 04040 | A | Rover1 | Albert mounts rover and commands it to drive back to the habitat. | | | | 18 |
| 04060 | H | Tablet2 | Hannah keeps track of camera feeds provided by Rover, looks out for alarms and requests sensor data. | | | | 19 |
| 04070 | A, R1 | A,H | Albert arrives back at habitat and mission is completed, Albert communicates arrival to Hannah. | | | | 20 |

**Table 36: Stepwise Decomposition of Problem Scenario (without ePartner) Phase 4**

## 9.2 STEPWISE DECOMPOSITION DESIGN SCENARIO IN NOMINAL CONDITIONS

| Step | A | T | Action | Reqs | Effect left tab (ECA) | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Rules required | Outline Step |
|---|---|---|---|---|---|---|---|---|---|---|
| *Phase 2: Clearing the surface – nominal condition (with ePartner)* | | | | | | | | | | |
| 01000 | A | R1 | Load supplies onto rover and mount it | | | | | | | 6 |
| 01005 | A | eP | Albert logs in on his device with a *username* and *password,* thereby gaining access to the up-to date knowledge base with all information relevant to the cache set-up mission | | | | | | | 6 |
| 01010 | A, R1 | eP | Drive Rover1 to planned location. | R025 (EFS) R027 (EFS) | A message 'Task *plan mission* has been completed' appears. | Depends on the tab that is selected. | Details are shown of a particular function, process, task or resource (depends on user choice). | The status of the task '*plan mission*' becomes *finished*, and that of the task '*drive to location*' becomes *busy*. | OR15 | 6 |
| 01020 | H | | Monitor processes relevant for EVA (rover status, Albert status, planning, schedule for | R013 (EFS) R003 (AUT, EFY,SAF, EMO, SAT) | | Depends on the tab that is selected. | Depends on the tab that is selected. | | | 7 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | task) on resource screen (map view, table view), and process screen. | R010 (EFS, SAT)<br>R004(SAW)<br>R002 (EFF, SAW) | | | | | | |
| 01030 | A, R1 | eP | Location has been reached. | R009 (EFY, SAW)<br>R010 (EFS, SAT)<br>R002 (EFF, SAW) | | | | The position of Albert and Rover1 have changed. | | 8 |
| 01040 | eP | eP | The next task in the general mission process becomes active (construct cache). The first task in this sub process is activated. | R025 (EFS)<br>R027 (EFS) | A message 'Task *drive to location* has been completed' appears. | | | The status of the task '*drive to location*' becomes *finished*, and that of the task '*clear area*' becomes *busy*. | OR15 | 9 |
| 01050 | eP<br><br><br><br><br><br>eP<br><br>eP<br><br>A | eP<br><br><br><br><br><br>eP<br><br>A<br><br>eP | Albert has a new task in his my task list (clear area),<br><br><br><br><br><br><br><br><br><br>and he starts performing the task (and clicks 'start'). | R023 (EFS, SAT)<br>R024 (EFS) | <br><br><br><br><br><br><br><br>A question 'You have a new task, do you want to start it?' appears. | <br><br><br><br><br><br>The task *'clear area'* is highlighted in the 'my tasks' tab. | <br><br><br><br><br><br>A 'start' button is shown.<br><br><br><br><br><br>Details of the task *clear area* are shown. | Task '*clear area*' is allocated to role *astronaut EVA*, which is enacted by Albert.<br><br><br><br><br><br>The task '*clear area*' is added to the 'my tasks' list of Albert. | DR2<br><br><br><br><br><br>DR7 | 9 |
| 01060 | A, R1 | eP | Change status in resource screen. Drive rover to rocks and remove them from location. | R041, R042 (CTL)<br>R010 (EFS, SAT)<br>R002 (EFF, SAW) | | Depends on the tab that is selected. | Depends on the tab that is selected. | The position of Albert and Rover1 have changed. | | 9 |
| 01070 | eP | A, H | Rocks have been removed from area, show current status in process screen. | R025 (EFS)<br>R027 (EFS) | A message 'Task *clear area* has been completed' appears. | The task *'drill holes'* is highlighted in the 'my tasks' tab. | | The status of the task '*clear area*' becomes *finished*, and that of the task '*drill holes*' becomes *busy*. | OR15 | 10, 11 |

**Table 37: Stepwise Decomposition of Design Scenario (with ePartner) Phase 2**

| Step | A | T | Action | Reqs | Effect left tab (ECA) | Effect middle tab (overv.) | Effect right tab (details) | Effect knowledge base | Rules required | Outline Step |
|---|---|---|---|---|---|---|---|---|---|---|
| *Phase 4: Return to habitat – nominal condition (with ePartner)* | | | | | | | | | | |
| 04010 | eP | eP | "return to habitat" task is activated | | Done in 03080. | Done in 03080. | Done in 03080. | Done in 03080. | Done in 03080. | 20 |
| 04020 | eP | H | Hannah is notified in process screen that Albert is in the next step (return to habitat) | R014 | | The process tab is shown, in which the *'cache construction process'* is highlighted. | All tasks of the process *'cache construction process'* are shown. The task '*return to habitat*' is highlighted. | | | 20 |
| 04030 | eP | eP | Receives information from the robot and sees that all processes are OK | R010 (EFS, SAT) | | Depends on the tab that is selected. | Depends on the tab that is selected. | The *BatteryStatus* of *Battery1* decreases gradually. | | 20 |
| 04040 | eP | A, H | Indicate the expected arrival time in process screen and that the Rover has enough battery level left | R023 (EFS, SAT) R027 (EFS) R031 (CTL, EFS) | A message 'Click here for explanation on task status' appears. | The 'my tasks' tab is shown, in which the task *'return to habitat'* is highlighted. | Details of the task *'return to habitat'* are shown, in particular the ETA and the task status (which is '*functional*'). | The task status of task '*return to habitat*' is '*functional*'. | OR11 | 21 |
| 04050 | H | eP | Click on explanation for battery level | | | See next step. | See next step. | | | 21 |
| 04060 | eP | H | Show in resource screen that the robot has enough battery level to finish the journey. | R010 (EFS, SAT) | | The resources tab is shown, in which *Battery1* is highlighted. | Details of *Battery1* are shown, in particular its *Battery Status*. | | | 21 |
| 04070 | A, R1 eP | eP A, H | Show in process screen that the EVA team has arrived at habitat | R023 (EFS, SAT) R025 (EFS) R027 (EFS) R002 (EFF, SAW) | A message 'Task *return to habitat* has been completed' appears. | The 'my tasks' tab is shown, in which the task *'return to habitat'* is highlighted. | Details of the task *'return to habitat'* are shown, in particular the taskrunstate (which is '*finished*'). | The position of Albert and Rover1 have changed. The status of the task '*return to habitat*' becomes *finished*. | OR10 | 22 |
| 04080 | eP | A, H | | R027 (EFS) | A message 'Process *cache construction* has been completed' appears. | | | The status of the process '*cache construction*' becomes *finished*. | | 22 |

**Table 38: Stepwise Decomposition of Design Scenario (with ePartner) Phase 4**

## 9.3 SIMULATION SCRIPT PROBLEM SCENARIO IN NOMINAL CONDITIONS

| **Mission Phase 2: *Approaching site and clearing the surface – nominal condition*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference** | **Simulated Mission Time Reference** | **Actions Albert (see Chapter** Error! eference source not found. **for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter** Error! eference source not found.**)** |
| S0 + 00:07:00 | M0 + 00:07:00 | Put on spacesuit and load cache payload onto rover **(see Step 01000)** | | 5 |
| S0 + 00:08:00 | M0 + 00:08:00 | Take seat/stand on rover **(see Step 01000)** | | 5 |
| S0 + 00:08:30 | M0 + 00:08:30 | Log into handheld device **(see Step 01005)**, command rover to drive to planned location **(see Step 01010)** and notify Hannah on voice loop about departure **(see Step 01010)**. | Use human mediated interface to make Eurobot move.<br>Initiate utility tool to cause gradually decreasing battery level to be displayed.<br>Announce on voice loop to Albert: You are now on your way to the planned cache location. | 5 |
| S0 + 00:11:00 | M0 + 01:30:00 *(Note time warp)* | *No actions yet.* | Inject cache location as rover position.<br>Use utility tool to adjust displayed battery level to reflect traveled distance (and being gradually decreased further).<br>Use human mediated interface to make Eurobot stop.<br>Announce on voice loop to Albert: | 7 |

| | | | | |
|---|---|---|---|---|
| | | | Almost one and a half hours have passed. You have now reached the cache location. | |
| S0 + 00:11:30 | M0 + 01:30:30 | Notify Hannah on voice loop that cache location has been reached **(see Step 01040)**. | | 7 |
| S0 + 00:12:00 | M0 + 01:31:00 | Look up next activity in agenda documentation **(see Step 01050)** and instruct rover to remove rocks from cache site **(see Step 01060)**. | | 8 |

**Table 39: Mission Simulation Script for Albert Phase 2 (Problem Scenario)**

| **Mission Phase 4: *Return to habitat – nominal condition*** | | | | |
|---|---|---|---|---|
| **Wall-clock Time Reference *(based on Phase 2)*** | **Simulated Mission Time Reference *(based on Phase 2)*** | **Actions Albert (see Chapter** Error! eference source not found. **for step references)** | **Actions WOZ** | **Problem Scenario Outline Step Reference (Chapter** Error! eference source not found.**)** |
| S0 + 00:17:00 | M0 + 01:38:00 | Notify Hannah that cache construction task is completed and trip back to habitat can begin **(see Step 04010)**. | | 18 |
| S0 + 00:17:30 | M0 + 01:38:30 | Agree with Hannah to begin trip back **(see Step 04030)**.. | | 18 |
| S0 + 00:18:00 | M0 + 01:39:00 | Mount rover and command it to drive back to habitat **(see Step 04040)**. | Use human mediated interface to make Eurobot move.<br>Use human mediated interface to specify power consumption according to nominal conditions (phase 2).<br>Announce on voice loop to Albert: You | 18 |

| | | | | |
|---|---|---|---|---|
| | | | are now on your way back to the habitat. | |
| S0 + 00:21:00 | M0 + 03:15:00<br>*(Note time warp)* | *No particular action*<br>**(see Step 04070)** | Inject habitat position.<br>Use utility tool to adjust battery level to traveled distance and nominal rover condition (Phase 2)<br>Announce on voice loop to Albert: About one and a half hours have passed. You have now reached the habitat.<br>Use human mediated interface to make Eurobot stop. | 20 |
| S0 + 00:21:30 | M0 + 03:15:30 | Notify Hannah on voice loop about arrival at habitat<br>**(see Step 4070)**. | | 20 |

**Table 40: Mission Simulation Script for Albert Phase 4 (Problem Scenario)**